International Energy Agency

Evaluation of Embodied Energy and GHG Emissions for Building Construction
Guidance to support construction product manufacturers in their decision making process

Energy in Building and Communities Program

November 2016

IEA EBC ANNEX 57

EBC is a programme of the International Energy Agency

IEA EBC ANNEX 57 | GUIDELINES FOR CONSTRUCTION PRODUCT MANUFACTURERS

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Final Version: November 2016

The preparation of this guideline was part of the Austrian contribution to the IEA EBC Annex 57, which is financially supported by the Austrian Research Promotion Agency (FFG) and the Austrian Ministry for Transport, Innovation and Technology (BMVIT), Grant #6069077 IEA RESEARCH COOPERATION.

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Australia, Austria, Belgium, Canada, Czech Republic, Denmark, France, Germany, Ireland, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States of America.

Published by Verlag der Technischen Universität Graz

ISBN (print): 978-4-909107-03-9
ISBN (e-book): 978-3-85125-519-5

http://dx.doi.org/10.3217/978-3-85125-519-5

Additional copies of this report, may be obtained from:
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Technikerstraße 4
8010 Graz
Austria
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The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 29 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA-EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBCS.) The research and development strategies of the IEA-EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. The research and development (R&D) strategies of IEA-EBC aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five focus areas for R&D activities:

» Integrated planning and building design
» Building energy systems
» Building envelope
» Community scale methods
» Real building energy use

The Executive Committee

Overall control of the IEA-EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA-EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA-EBC Executive Committee, with completed projects identified by (*):

Annex 1: Load Energy Determination of Buildings (*)

Annex 2: Ekistics and Advanced Community Energy Systems (*)

Annex 3: Energy Conservation in Residential Buildings (*)

Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)

Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)

Annex 48: Heat Pumping and Reversible Air Conditioning (*)

Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)

Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)

Annex 51: Energy Efficient Communities (*)

Annex 52: Towards Net Zero Energy Solar Buildings (*)

Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods (*)

Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings (*)

Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO) (*)

Annex 56: Cost Effective Energy & CO2 Emissions Optimization in Building Renovation

Annex 57: Evaluation of Embodied Energy & CO2 Equivalent Emissions for Building Construction

Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements

Annex 59: High Temperature Cooling & Low Temperature Heating in Buildings

Annex 60: New Generation Computational Tools for Building & Community Energy Systems

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Working Group - Energy Efficiency in Educational Buildings (*)

Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)

Working Group - Annex 36 Extension: The Energy Concept Adviser (*)

MANAGEMENT SUMMARY

This guideline summarizes selected results and recommendations of the IEA-EBC Annex 57 dealing with the “Evaluation of Embodied Energy and CO2eq for Building Construction”. The specific mission of Annex 57 was to develop and provide the necessary methodological bases, tools, calculation rules, data bases and application examples for incorporating the aspects of embodied energy and GHG emissions into the decision-making of relevant stakeholder groups. The results are published in the form of thematic sub-reports and specific guidelines for selected groups of stakeholders in order to cater their differentiated needs and requirements.

Annex 57 includes the following series of guidelines:

- Guideline for designers and consultants – part 1: Basics for the assessment of embodied energy and GHG emissions
- Guideline for designers and consultants – part 2: Strategies for reducing embodied energy and GHG emissions
- Guideline for SMEs of construction product manufacturers
- Guideline for policy makers, including recommendations for public procurement
- Guideline for educators and university professors

EBC
Energy in Buildings and Communities Programme

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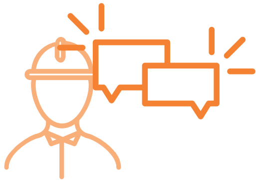

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PART 01 — THE IMPORTANCE OF CONSIDERING EMBODIED IMPACTS AS AN ADDITIONAL ASPECT IN YOUR DAILY PRACTICE

» Embodied impacts — an additional aspect in the manufacturing and marketing process for construction products
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» Application possibilities

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» Description of the product
» Selection and description of the system boundaries
» Collection, processing and presentation of information on individual life cycle stages
» Compilation and analysis — reporting and communication

INTRODUCTION

This guideline is targeted specifically to construction product manufacturers. The aim is to **raise the awareness on the subject of embodied impacts in relation to construction products**, to present the starting points for the integration of embodied impacts assessment into the continuous improvement of production-related processes and product-related characteristics and information. One additional target is to provide acacess to related guidance, data, information sources and assessment tools respectively. This guideline is specifically intended for use by **small and medium-sized manufacturing enterprises (SMEs)** seeking to improve their market competitiveness usually hindered by lack of resources and limited access to information.

The purpose of this guideline is to improve the understanding and management of embodied impacts of construction products and related primary raw materials across the construction product-manufacturing sector. In assistance of the SMEs in the construction products industry this guideline document provides:

a. **methodological guidance** for a simplified calculation and assessment of embodied impacts
b. **recommendations** to improve the production and procurement processes as well as related environmental product information
c. options for the **declaration of environmental product information**. In addition, it is indicated which relationships exist between investigating embodied impacts and creating an environmental claim, such as e.g. an Environmental Product Declaration (EPD).

Since the first oil crises in the 1970's operational energy efficiency has become an increasingly important aspect of the design of buildings, as well as a subject of legislation. As a result, the operational energy and related operational impacts of new buildings have decreased considerably since that time. **FIGURE 01** pictures schematically the ratio between the operational impacts and the embodied impacts due to the erection of a building till it´s end of life (EoL). It can be noted that embodied impacts are gaining more and more importance due to the increasing use of building products, e.g. thermal insulation.

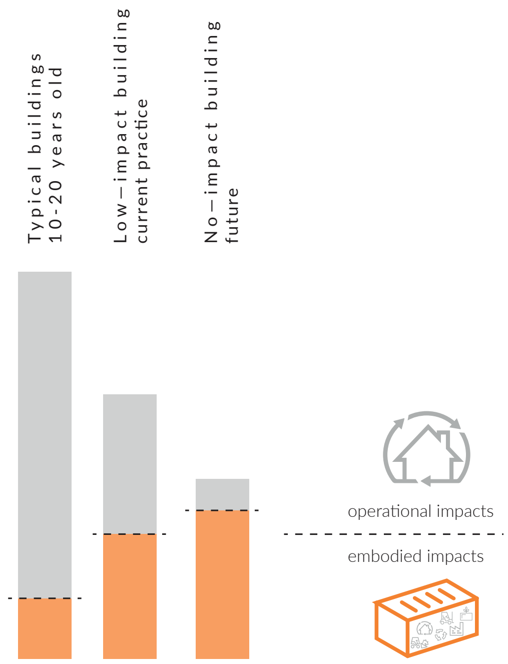


FIGURE 01 | THE RATIO OF OPERATIONAL AND EMBODIED IMPACTS IN THE COURSE OF TIME

Specifically, in this document, the term **"embodied impacts"** refers only to the primary energy consumption and the adverse effects on the climate resulting from green house gas (GHG) emissions that arise in the life cycle of construction products due to their production, installation into the building or construction works, maintenance and end of life; the so-called embodied energy and embodied GHG emissions. These have a great influence on the embodied impacts for building construction in connection with the use of resources (in this case energy resources) and the adverse effects on the environment (here global warming potential - GWP).

FIGURE 02 shows that embodied impacts can occur at different stages of a building product's life cycle. Construction product manufacturers have a significant influence from raw material supply to manufacturing process over the building use phase and end-of-life and related recovery, reuse, recycling potential respectively. In contrast to other aspects, the embodied impacts are directly linked to a particular building product but can not explicitly be recognised as such, wherefore the construction product manufacturers need to pay special attention to them.

In this guideline, essential results of the International Energy Agency – Energy in Buildings and Communities Programme (IEA EBC) Annex 57 "Evaluation of Embodied Energy & Embodied GHG Emissions for Building Construction" are summarized and specific recommendations are presented, accompanied also by supporting information. Specifically, construction product manufacturers are strongly advised to inform themselves concerning the applicable methodological guidance, the recommendations given to improve their production and procurement processes as well as related environmental product information.

This publication is part of a series of guideline publications targeted to specific groups of actors working within the AEC industry (architects, engineers and construction product manufacturers, policy makers, procurers), and the education sector (educators).

Detailed information on basics, as well as background information on system boundaries, and specific indicators is available in detailed reports developed as part of the subtasks "**ST1 — Basics, Actors and Concepts**" and "**ST3 — Review of Methods, Emerging Research and Practical Guidelines**" of IEA EBC Annex 57. These reports can be found here: www.annex57.org

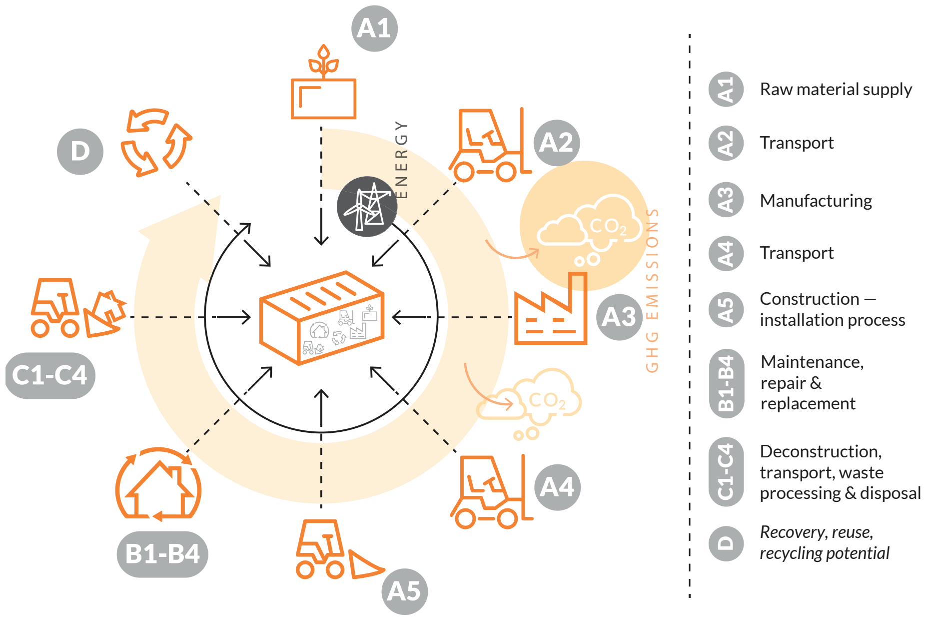


FIGURE 02 | EMBODIED IMPACTS AS A RESULT OF DIFFERENT PRODUCT LIFE CYCLE STAGES

PART 01 | EMBODIED IMPACTS — AN ADDITIONAL ASPECT IN THE MANUFACTURING AND MARKETING PROCESS FOR CONSTRUCTION PRODUCTS

Construction product means any product, which is produced and placed on the market for incorporation in a permanent manner in construction works (here buildings or constructed assets) or parts thereof, and the performance of which has an effect on the performance of the construction works. Construction products can be made of a variety of materials, which are manufactured into a myriad of products and are then combined together to create buildings or infrastructure.

The **embodied impacts** of a construction product must always be considered and assessed only in the context of the role it performs in a building. This means that the contribution of product related characteristics to the functional and technical performance but also the environmental, social and economic performance of construction works should alwas be taken into account. For example, insulation materials make buildings more energy efficient in the operational phase, but that benefit may outweigh the embodied impacts of its manufacture, replacement and end-of-life (EoL).

TABLE 01 shows how construction product manufacturers can achieve business goals supported by the incorporation of embodied impacts within the objectives of climate change management, hotspot analysis and performance tracking, customer and supplier management and improvement of market competitiveness and product unique selling proposition.

Currently, many legislative regulations exist for testing, inspection and certification of building materials and their harmonized technical characteristics (e.g. the Construction Products Regulation (CPR) in Europe).

TABLE 01 | SHOWS HOW CONSTRUCTION PRODUCT MANUFACTURER CAN ACHIEVE BUSINESS GOALS SUPPORTED BY THE INCORPORATION OF EMBODIED IMPACTS.

BUSINESS GOAL	DESCRIPTION
Climate change management	Identify energy and environmental related risks in product’s life cycle Hotspot and risk analysis from fluctuations in energy and material availability
Hotspot analysis and performance tracking	Assess and report of environmental product performance Strategic product-related reduction of embodied impacts Lift cost-saving opportunities through reduction of embodied energy and related impacts Lift cost-saving opportunities through reduction of embodied energy and related impacts
Customer and supplier management	Assess supplier performance for embodied impacts Reduce embodied impacts in the supply chain Marketing of environmental performance Provide additional products related information
Improvement of market competitiveness and product unique selling proposition	Identify new market opportunities Strengthen company image regarding environmental performance Redesign of products to better respond to customer and policy preferences Achieve competitive advantage by pursuing embodied impacts reduction opportunities

Hence, for construction product manufacturers the development and manufacture of environmentally responsible construction products as a voluntary task is no longer an exotic topic, but a necessity. Through national and regional policies and legislations, such as the European Sustainable Consumption and Production (SCP) policies and the European Registration, Evaluation and Authorization and Restriction of Chemicals Regulation (REACH), manufacturers are called upon to play their part in the implementation of the principles of sustainable development, among others.

Nowadays, clients, procurers and designers, seek to select construction products to fulfil not only the requirements on the functional and technical quality and economic aspects, but also to contribute to the conservation of resources and the reduction of adverse effects on the environment as part of an overall strategy for sustainable design and construction. In addition, they want to contribute to the health, comfort, safety and general user satisfaction and minimize risks for the contractor at the site. Usually such requirements are already formulated at the pre-design stages in the clients' brief and later on in the tender documentation. It is no surprise that currently the construction product manufacturers are being asked to step up to this challenge and respond to questions about the embodied impacts of their products in one way or another.

In addition, across the world, various standards and building rating / sustainability assessment schemes are harmonising environmental performance assessment. The result is a high demand for construction-related information as a basis for an environmental or sustainable performance assessment of construction works. Therefore, transparent, robust, consistent and verified information are required to incorporate the product related information into the design and assessment process.

Increasingly, tools are emerging to link embodied impacts with operational impacts from a life cycle perspective thus enabling a better understanding of the trade-offs between operational and embodied impacts and aimed at improving decisions at the design stage. Moreover, designers are combining life cycle assessment (LCA i.e. environmental impacts) and life cycle cost (LCC i.e. economic) and linking them with BIM (Building Information Modelling). All of which contributes greatly to the goal of energy efficiency, low carbon, resource efficiency and a more sustainable built environment.

In this regard, it is becoming increasingly necessary for the manufacturers not only to understand and assess in a targeted manner how their decisions related to the product and process optimisation influence these important environmental issues taking into account the full life cycle of construction products, but also to find ways to communicate this information effectively to other stakeholders along the supply chain (e.g. relevant standards have been published under the responsibility of ISO/TC 59/SC 17 and CEN/TC 350). This includes the embodied impacts associated with the production, installation, use and end-of-life of construction products.

Specifically, the importance of investigating and documenting these aspects lies in the following reasons (see also **FIGURE 03**):

» ISO 21930 (ISO/TC 59/SC 17) and EN 15804 harmonize environmental-related data on construction products. These include the necessary emissions information on the embodied energy and embodied GHG emission used as a basis for environmental performance assessment on the building level.

» UNEP-SBCI has developed since 2012 a new Task Force on "Greening the Building Supply Chain" (Technical Report: http://www.unep.org/

sbci/pdfs/greening_the_supply_chain_report.pdf), with the aim to draw attention, even more than has been the case, on embodied impacts.

- The European Construction Products Regulation (Cpr) includes an additional basic requirement on the sustainable use of natural resources (Basic Requirement No 7, REGULATION (EU) No 305/2011)
- Product responsibility is part of a company-related sustainability policy and reporting.
- The increased presence of green or sustainable public procurement will drive increasing demand for environmental and health friendly products on the market.
- Low embodied impact related manufacturing processes and products (fewer energy resources and less environmental pollution) result for the most part in an improved financial performance as the enterprise pays less for inputs, as well as for waste and pollution management.
- Manufacturers who quantify, assess and publish LCA data demonstrate their own commitment to reporting and continuous improvement, providing a basis for communication with other stakeholders – this leads to an increased credibility.
- Holistic sustainable building assessment and certification systems rely on comprehensive and detailed environmental information of construction products, such as LEED, BREEAM, DGNB/BNB, HQE, TQB, SBTool and others.
- Various environmental information claims (e.g. EPDs) allow designers to make more efficient and effective product and construction comparisons. Recently the introduction of the product environmental footprint (PEF) to complement the EPD concept is currently discussed in Europe.
- These environmental information (LCA, EPD, PCF, PEF as well as other environmental labels) are used for communication along the supply chain.
- Architects and engineers as well as clients and purchasers, who are driving the demand for environmentally responsible products, increasingly require low embodied impact products, as well as objective, unbiased and transparent technical and environmental information about the construction products
- The design process is increasingly being digitalized e.g. by the use of BIM (Building Information Modelling), which allows the calculation of whole building related operational and embodied impacts, and may drive requirements for product-related data.
- In many countries, publicly accessible databases and information platforms are established and expanded to support the selection of construction products. In order for the manufacturers to be represented in those information systems, it is necessary for them to provide product-specific environmental information (including resource use and impacts on the global environment).

Especially for SMEs (a definition by the European Union can be found here http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/index_en.htm) of construction product manufacturers, the ability to respond to the challenge of dealing with issues related to the description, evaluation and management of embodied impacts:

- enhances their overall image and level of competitiveness on the market
- demonstrates the institutional commitment to, and acceptance of responsibility for the environment and society
- lifts cost and risk reduction through energy and resource efficiency and substitution

The embodied impacts of construction products should not be assessed without the consideration of the functional and technical performance at the building level, as these are only partial aspects of a complex debate on the issue of overall quality and characteristics of construction products and their intended use. Evenly important is the consideration of the full life cycle to avoid the burden shifting and trade-offs. However, for manufacturers who already work their way into these complex issues, the engagement with issues related to embodied impacts is a perfect start.

Most of the relevant information is thereby already documented internally (e.g. by the manufacturers factory production control according the CE-marking) and can easily be expanded and evaluated in terms of embodied impacts. LCA, EPDs or PEFs are possible options to provide verified data on environmental / embodied impacts.

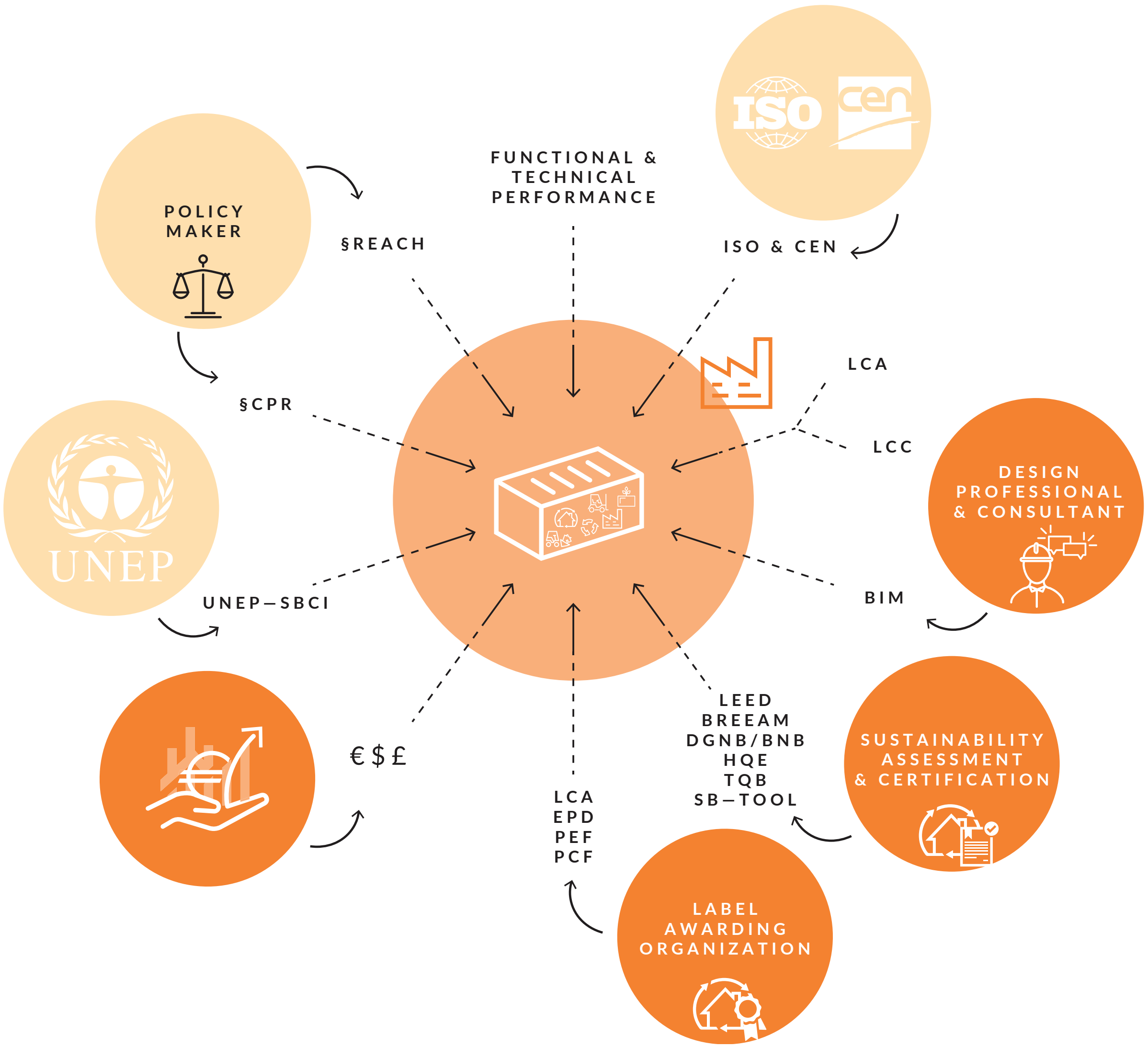


FIGURE 03 | INFLUENCES ON CONSTRUCTION PRODUCTS

THE ROLE OF MANUFACTURERS IN THE LIFE CYCLE ORIENTED SUPPLY CHAIN

The flow of materials, information, money and services for construction products is characterized as follows: From raw material suppliers through construction product manufacturers (cradle to gate) the products are incorporated into the building. Over the life cycle, some products need to be repaired and replaced and need to be treated at their end-of-life respectively. **FIGURE 04** shows the supply chain.

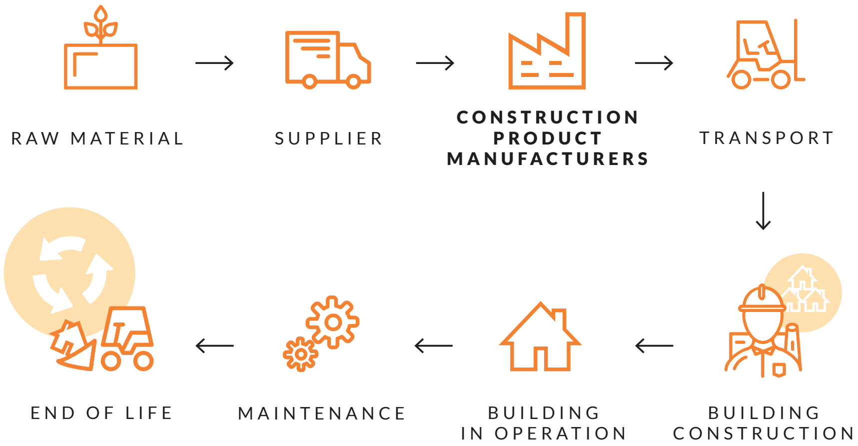


FIGURE O4 | THE SUPPLY CHAIN

Today, more than in the past, construction product manufacturers are confronted with requirements for information about additional technical characteristics, installation, long term durability, behavior, maintenance and maintainability as also end-of-life phase scenarios or recyclability of their products related to sustainable use of natural resources and environmental protection goals. These requirements need to be taken into account and managed by construction product manufacturers additively to the traditional (harmonized) requirements for information about technical, functional or economic performance of their products. In addition to maintaining a high level of quality for the products, the supply, availability and quality of comprehensive product information becomes a requirement for the company's success.

Manufacturers can encounter along the development and manufacturing process of their products various issues related to the description, calculation and treatment of embodied impacts. The AEC and building clients as well as developers are moving over to formulating specific requirements for sustainability as an addition to the requirements for technical, functional or design quality of construction works and pushing designers, contractors and vendors to choose construction product manufacturers and products, which comply with these requirements. This includes the setting of targets for the reduction of embodied impacts due to the construction, maintenance and end-of-life of construction works.

The group of construction product manufacturers, in its attempt to accept its responsibility for environment and society, can use its power of influencing the embodied impacts of their products through, for example, the choice of specific primary raw materials, energy sources and technologies for the manufacturing process. These choices should be taken into account in the evaluation and selection of production process alternatives. Beyond this, they can further develop the technical characteristics of their products in terms of durability, maintainability and serviceability, as well as ease of dismantling, reuse and recyclability. At the same time, they can expand their operations on the product life cycle through life cycle support services (e.g. maintenance contracts) and finally take back products at the end of their service useful life. In addition, they can technically advise and support clients and architects in the selection and the intended use of their products. This proof of competence and the provision of “green” products in combination with the publication of relevant additional environmental product information, as well as the transition to life cycle support services, can improve the competitive position of SMEs.

SMEs supply products and product-related information to large retailers and construction companies. SMEs have particular characteristics that can present challenges due to

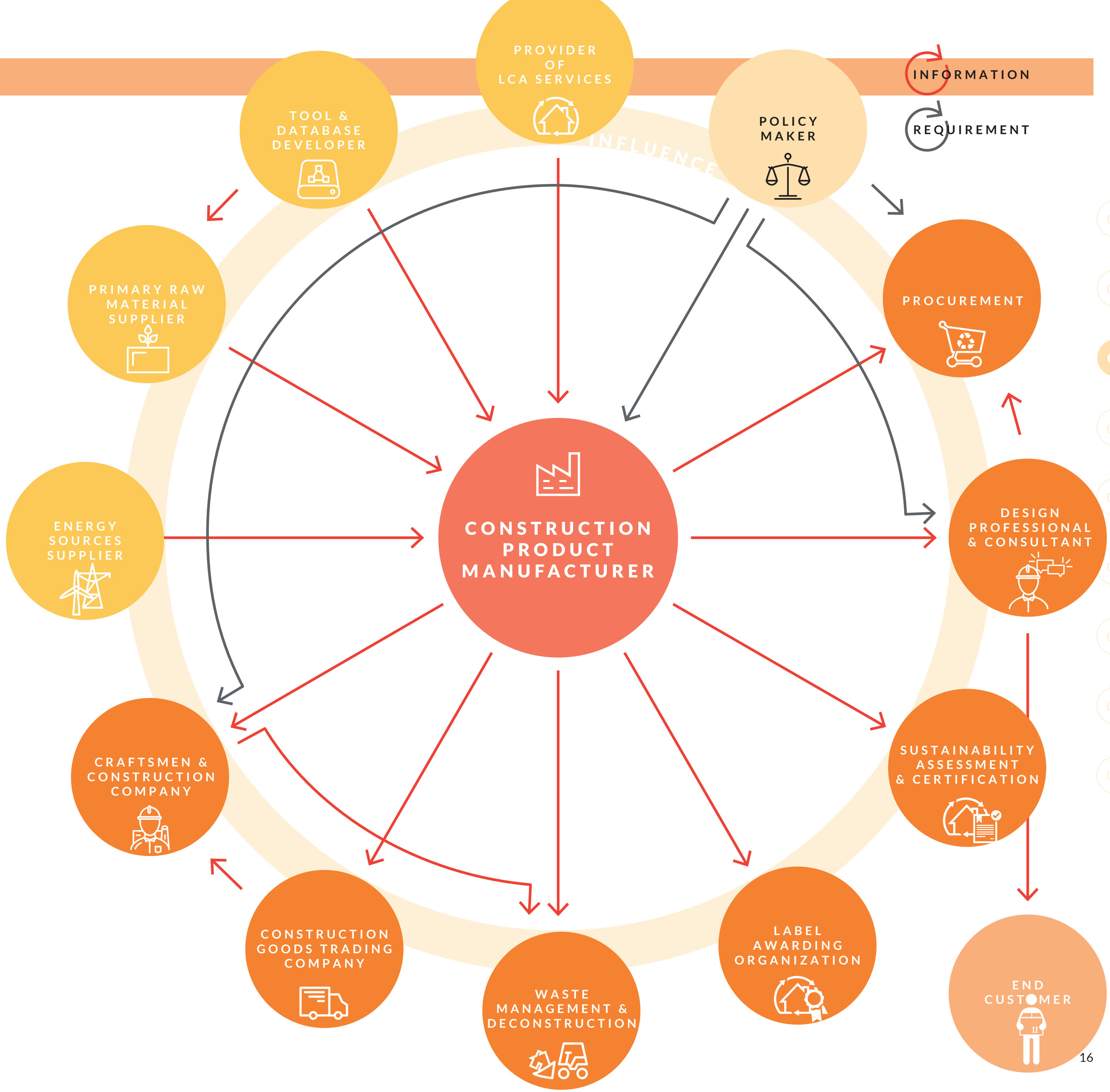


FIGURE 05 | INFORMATION EXCHANGE BETWEEN CONSTRUCTION PRODUCT MANUFACTURERS AND OTHER STAKEHOLDERS the presence of fewer technical and financial resources for gathering data across different parts of the business operations and the overall adoption of a strategy for the measurement and monitoring of their products' embodied impacts.

Construction product manufacturers need to collaborate and exchange information with other groups of actors in order to fulfill their tasks. Information is beeing exchanged between various stakeholders from and to manufacturer. **FIGURE 05** gives an overview of this processes.

These groups are, among others:

» **Primary raw material suppliers and intermediate products manufacturers/ suppliers** – they provide the vital information to construction product manufacturers about the primary raw materials and intermediate products they use for the manufacturing of the final product. The nature and extent of the information provision should be contractually regulated between the supplier and the manufacturing company.

» **Energy sources suppliers** – they provide information to the construction product manufacturers about the different energy sources to be used in the manufacturing process. The nature and extent of the information provision should be contractually regulated between the energy source supplier and the enterprise. Here, the provision of specific primary energy and emission factors is of great importance. For the energy suppliers themselves cheap primary energy and emission factors become an additional competitive characteristic.

» **Construction goods trading companies** – they desire and need to provide information and advise their customers not only in terms of the technical properties of the product, but also in terms of its environmental and health performance. In some cases, they develop separate DIY exhibition areas or special assortments with more environmentally friendly products.

» **Craftsmen and construction companies** – besides the technical specifications of the products, they are also interested in instructions for product processing and waste handling ocurring due to product processing. In the area of auxiliary construction materials or in construction projects with a functional tender, construction companies have partially the responsibility for the selection of products, and therefore they need to include in their selection process information about the environmental and health impact of the products. Provided that they also perform maintenance and servicing work, they need information on the service life, as well as the ease and frequency of service and maintenance.

» **Deconstruction and waste management companies** – they are particularly interested in the dismantling and recycling properties of the products and need appropriate information.

» **Specialist providers of LCA services** – they are commissioned by the construction product manufacturers or their organisation to calculate LCA data and develop EPD's. Since the SMEs have limited financial resources, they are less inclined to engage in development of LCA and EPD through an LCA specialist.

» **Tool and database developers** – they obtain information by the construction product manufacturers on the environmental characteristics, service life and maintenance cycles of different construction products following a specific format (sometimes in the form of EPD's), so that to make them available for design professionals and consultants, as well as LCA specialists in their platform. Also manufacturers themselves obtain environmental information for the primary products they use in manufacturing of their final product from different databases.

» **Design professionals and consultants** — they obtain information on the environmental characteristics, service life and maintenance cycles of their selected construction products in the form of EPD's either directly from the construction product manufacturers, or indirectly from EPD's being integrated into databases and tools.

» **Procurers** — they integrate requirements to reduce embodied impacts into the client's brief, invitation to tenders, contracts and other documents. In this context, construction product manufacturers need to provide data and credentials for the embodied impacts of their products to this actor group.

» **End-users/Consumers** — building products consumers are increasingly interested in the environmental and health related impacts of the products they buy in the DIY store. Some of them base their purchasing decisions on eco-labels or information on the carbon footprint. It is becoming increasingly important to communicate such information to the customer. Finally, end users have an influence on the useful life of the product, and therefore, they need instructions for proper use, for cleaning and maintenance.

Between these groups of actors, the information exchange must be organized and carried out in an appropriate manner.

Other actor groups with whom construction product manufacturers collaborative relationships may form, are:

» **Policy makers** — they formulate, for example, objectives and requirements in relation to embodied impacts and their declaration and, if necessary, these are taken into account in respective funding programs.

» **Organizations promoting sustainability assessment and Building certification** — they request the data related to embodied impacts in order to include these in the building assessment. In turn, they also make available data and tools. (e.g. LEED, BREEAM, DGNB/BNB, HQE, TQB, SBTool and others).

» **EPD program operators** — are organizations for LCA-based environmental claims and assist manufacturers with the preparation and certification of an Environmental Product Declaration (EPD) – type III labels (ISO 14025:1999). In most cases they manage the entire process from start to finish, including the provision of harmonized rules i.e. the PCR documents and/or verify the results.

» **Label awarding organizations** — organizations that award type I labels (ISO 14024:1999) require a reliable basis for data. This includes information on embodied impacts.

APPLICATION POSSIBILITIES

To enhance the benefits to the manufacturers as well as to stakeholders over the life cycle of a building, primary goals must be set and dedicated to life cycle phases. The specific course of action in relation to embodied impacts and possible methods to be applied must be chosen. **FIGURE 06** exemplary pictures possible methods to be applied in life cycle phases A1 to A3. With regard to the advanced optimization targets (reduction of embodied impacts) multi criteria decision making (MCDM) A can support decision-making processes (e.g. raw material or transport options, integrated process optimization in manufacturing, etc.). Necessary information can be gathered by environmental product declarations & relevant labels B. Regarding life cycle phase A3 improved life cycle thinking C and maturity assessments D are essential to achieve both benefits in product stage and in use and EoL phase respectively. Individual benefits due to

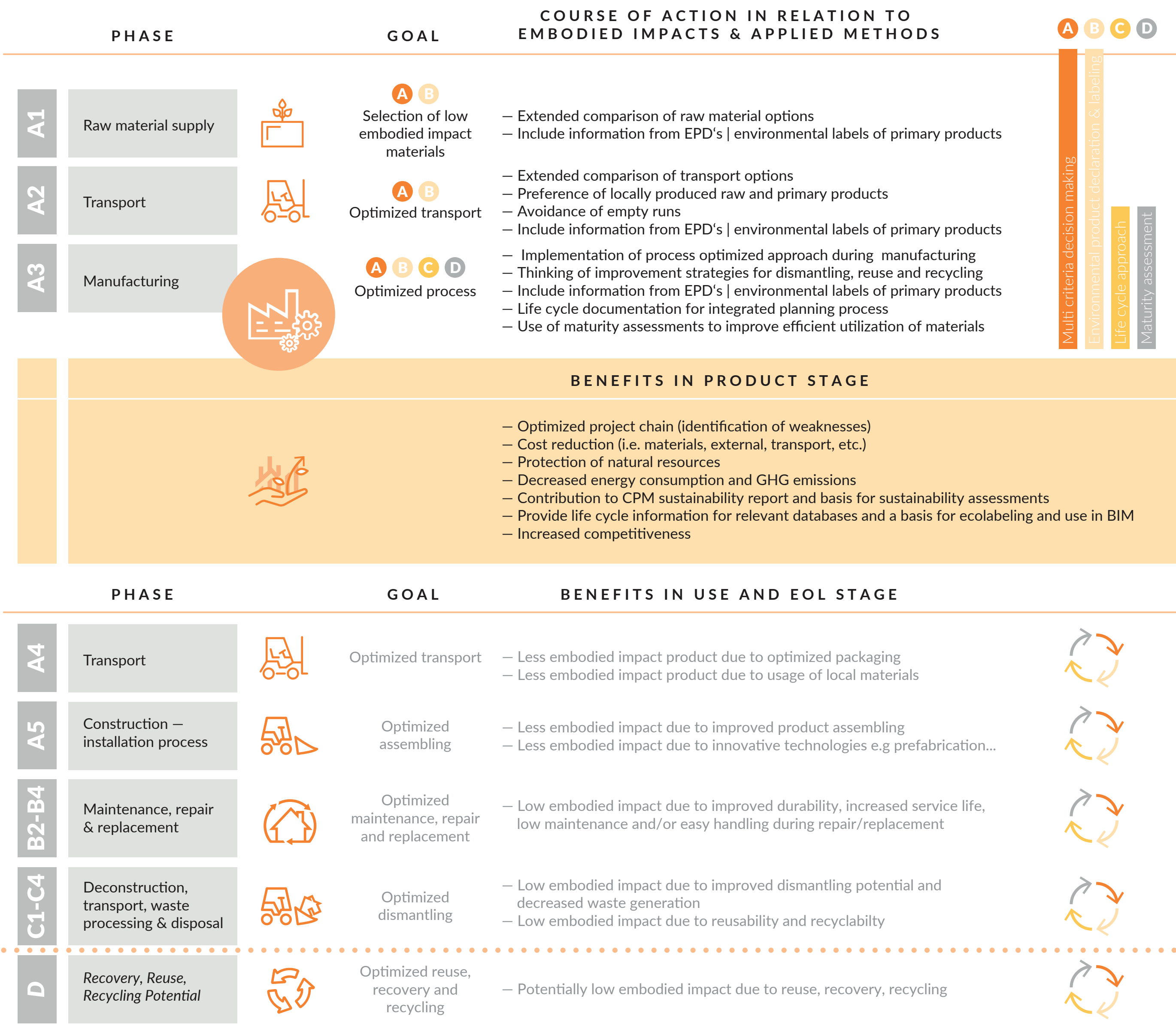


FIGURE 06 | COURSE OF ACTION AND BENEFITS IN RELATION TO EMBODIED IMPACTS optimization efforts in early life cycle phases are pictured exemplarity in **FIGURE 06** and described in the following application possibilities.

1. OPTIMIZATION OF PROCESSES WITHIN THE ENTERPRISE

Performing a life cycle assessment (LCA) for a product can help its manufacturer in identifying potential for production processes improvement and ways of optimising the product towards a highly competitive product. Problematic aspects of the production chain can be identified and tackled. Additionally, suggestions for better raw materials/pre-products, energy supply sources and technology choices can be made based on an embodied impacts analysis.

2. CONTRIBUTION TO LOWER COSTS THROUGH ENERGY CONSERVATION AND SUBSTITUTION

Producing with less embodied impacts (fewer energy resources and less pollution) results for the most part in an improved financial performance as the enterprise pays less for inputs, as well as for waste and pollution management.

3. IN-HOUSE COMPARISON OF LOCATIONS/SITES

For enterprises operating in more than one location, it is important to compare the different manufacturing technologies used in the different locations, so as to identify which locations are associated with the higher embodied impacts – identification of hotspots.

4. BENCHMARKING FOR THE ENERGY INTENSITY OF PRODUCTION (INDUSTRY COMPARISON)

The establishment of benchmarks from the industry for the energy intensity of the different production processes is important for recognizing those products that achieve the relevant reductions from the average (low impact products). It is recommended that manufacturers actively engage in reducing their product's carbon-equivalent footprint and work with their industry associations to develop generic Environmental Product Declarations (EPDs) for their product category.

The benchmarks are usually developed on the basis of representative, Life Cycle Inventory data published in national databases or are set by generic, or representative, EPDs for each product category. Product manufacturers are encouraged to work with their industry associations to provide transparent LCA data that can serve as an example and benchmark for their product. Once established, a link to these benchmarks can be made.

5. CONTRIBUTION TO THE ENTERPRISE'S SUSTAINABILITY REPORTING

The embodied impacts results indicating reductions in energy consumption and environmental impacts of the manufacturing or corporate processes constitute an important input to the enterprise's Sustainability Report, and therefore, have an impact on the image and value of the enterprise. Product responsibility can be better demonstrated when offering take-back-guarantees and publishing appropriate product-related information.

6. COMPILATION OF INFORMATION FOR BUSINESS-TO-BUSINESS (B2B) OR FOR BUSINESS-TO-CONSUMER (B2C) COMMUNICATION

Nowadays, the products purchasers expect the product provider to include information on their products environmental and health-related impacts including also embodied impacts related information. Only this enables them to determine themselves in a cost and time efficient manner the cumulative impacts up to the manufacturing stage. The demand for such information is expected to grow even further.

End customers are increasingly interested in information on carbon footprint. In particular, for products that are traded in hardware stores, it is increasingly important to make this information available.

7. APPLICATIONS FOR ECOLABELS AND EPD

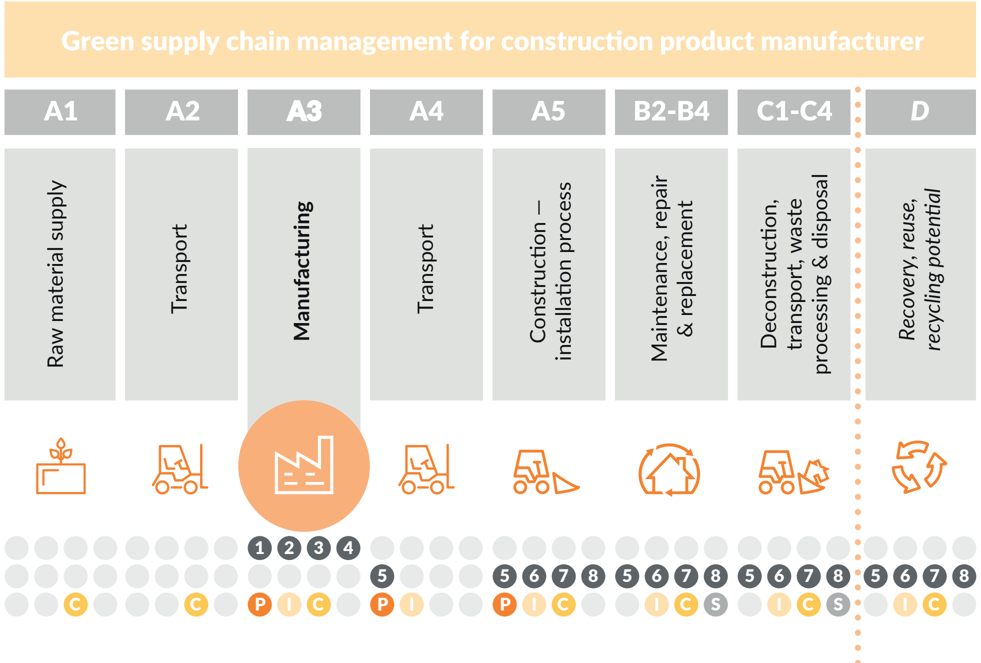
Some label awarding organisations for environmental labels require the presence of information on embodied impacts in addition to other environment and health related information.

There are several reasons why EPDs are of special interest for construction product manufacturers. EPDs are useful in the course of process and product optimisation. They offer leverage in negotiations with primary product suppliers, and are an ideal marketing tool and a means to communicate product information to stakeholders in the building industry. The results of an embodied impacts assessment can be an input to the EPDs.

8. PROVISION OF DATA FOR DATABASES

It is important for construction product manufacturers to communicate embodied impact information associated with the production, installation, use and disposal or recycling of construction products effectively to the stakeholders (e.g. clients, designers, purchasers, etc.) along the building supply chain. For example, the resulting data provided by the construction product manufacturer can be made available in databases for design professionals and consultants, as well as LCA specialists. In any case, manufacturers need to display the embodied impact of a product in a simple way, which is easy to understand for the user. Comparing different products and their specifications thus becomes less challenging.

The application of the previously described measures contributes additionally to "green" supply chain management. Improvements may occur in term of product, information, cost or service. In this case, the latter is associated with enhancements in maintenance and deconstruction processes. To summarize, the relevance of application possibilities in context to possible benefits in a green supply chain are shown on the next page in **FIGURE 07.**



APPLICATION POSSIBILITIES & LIFE CYCLE BENEFITS

P	**PRODUCT**	1	Optimization of the processes within the enterprise
I	**INFORMATION**	2	Contribution to lower costs through energy conservation and substitution
C	**COST**	3	In-house comparison of location | site
S	**SERVICE**	4	Benchmarking for the energy intensity of production (industry comparison)
		5	Contribution to the enterprise's sustainability reporting
		6	Compilation of information for B2B and B2C communication
		7	Applications for ecolabels and EPD
		8	Provision of data for databases

FIGURE 07 | APPLICATION POSSIBILITIES OF AN ASSESSMENT OF EMBODIED IMPACTS AND RELATED BENEFITS ACROSS THE LIFE CYCLE

PART 02 | BASICS, TERMS AND DEFINITIONS

1. THE CONCEPT OF EMBODIED IMPACTS

All products, not just construction products, have an impact on the environment (change to the environment that can be either adverse or beneficial). This impact can occur at any time during their production, use or end-of-life treatment. All these stages are collectively referred to as product life cycle. The measurement of this environmental impact is called Life Cycle Assessment (LCA). The assessment's goal and scope definition is the first step, followed by the Life cycle Inventory (LCI), life cycle impact assessment (LCIA) and finally interpretation and communication of assessment results. LCI is the accounting of all the flows in and out of the product system, including the energy and raw material inputs and environmental releases associated with each life cycle stage. This kind of analysis can be extremely complex and may involve a whole range of individual unit processes in a supply chain associated with several hundred separate materials and energy inputs and outputs, as well as emission releases to be tracked. In most cases the relevant information can be taken from a factory production control and related quality management documents in addition to the information from the suppliers. The environmental impacts related to the emissions in an LCA are then evaluated in next mandatory step - the so called LCIA.

One option to communicate the environmental impacts of a product, e.g. the result from a LCA, in a standardized manner is an Environmental Product Declaration (EPD). It is based on harmonized rules known as Product Category Rules (PCR). The purpose of PCR is that the methodology to assess environmental indicators, such as embodied GHG or embodied energy, for a construction product should be based on common rules and in thus eliminate national regulations and declarations that act as trade barrier.

When an environmental impact of a product is characterized as "embodied" (or "embedded" or "grey") it does not mean that it is physically embodied in the product itself. It is used in a metaphorical sense to describe the impacts caused by life cycle stages of a product other than the stages related to the operation of the building (embodied in a virtual sense; thus considered as if that impacts were incorporated or "embodied" in the product itself). The concept is useful as a way of allocating the energy and material flows to a product or service.

2. TERMS AND DEFINITIONS

Embodied impacts refer in this document only to the primary energy consumption and the adverse effects on the climate resulting from GHG emissions that arise in the life cycle of construction products due to their production, installation into the building or construction works, maintenance and end-of-life; the so-called embodied energy and embodied GHG emissions. These have a great influence on the embodied impacts of buildings and construction works in connection with the resource use (in this case energy resources) and the adverse effects on the environment (here GWP). In general embodied impacts are linked to all kind of specific embodied emissions (e.g. acidification potential AP , etc.)

In this guideline, the focus is on “embodied energy” and “embodied GHG emissions”, which are defined as follows:

Embodied energy (EE) (sometimes also called cumulative energy demand) is a method of accounting for the primary energy resources, regardless of their type, consumed/used in one or more life cycle stages of a given product (of a given functional equivalent), other than the ones related to the direct use of the product or to the operation of the construction work (this applies only to buildings and products, which are relevant for the energy supply of a building).

Embodied GHG emissions (EG) (sometimes also called embodied carbon, carbon footprint or embodied global warming potential) is a method of accounting for the amount of greenhouse gases, regardless of their type and source — check note 1 and 2, emitted during one or more life cycle stages of a given product (of a given functional unit), other than the ones related to the direct use of the product or to the operation of the construction work (this applies only to buildings and products, which are relevant for the energy supply of a building).

FIGURE 08 displays the upstream, the production and the downstream process as well as the product manufacturers' direct influence. A more detailed description is given in Chapter 06 - The perspective of upstream and downstream processes on page 28.

Note 1: The types of GHG emissions covered in an assessment of “embodied GHG emissions” can be:

» carbon dioxide (CO_2) alone;

» the main (groups of) gases identified in the Kyoto Protocol (CO_2, CH4, N2O, HFCs, PFCs, SF6 and NF3);

» the numerous GHGs specified by the 5th IP CC report (2013);

» the numerous GHGs specified by the 5th IPCC report (2013) including also the fluorocarbon (F-gases) regulated under the Montreal Protocol.

Note 2: In general, the majority of embodied GHG emissions associated with construction products arise directly from the use of energy – for example from the combustion of fossil fuels in power stations, boilers, furnaces, kilns and engines. Both the emissions associated with the energy conversion processes occurring at the enterprise's own premises (owned or controlled by the company) and the ones associated with the generation of purchased electricity and district heat should be accounted for (the so-called scope 1 & 2 emissions). These are the **fuel-related GHG emissions**, which are the most significant.

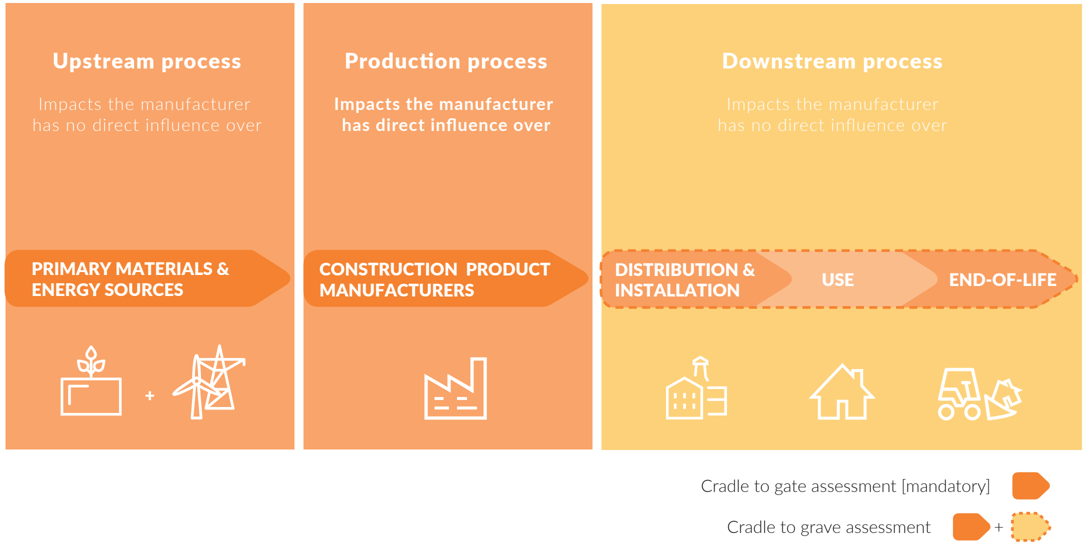


FIGURE 08 | PRODUCT LIFE CYCLE ACCOUNTING ACCORDING TO PRODUCT LIFE CYCLE ACCOUNTING AND REPORTING STANDARD

However, these do not give the whole picture. There are also the **non-fuel related CO_2 emissions** arising from:

- » the manufacturing processes (the so-called process-related emissions) as a result of specific chemical effects (e.g. CO_2 is emitted as a chemical reaction in cement manufacture)
- » the potential for some materials and products to emit Fluorocarbon gases (F-gases) during their use in the building's operation, e.g. when F-gases such as HCs, HFCs, HCFCs, have been used as blowing agents in insulation materials for buildings and as refrigerants in cooling systems.

In the case of bio based products (e.g. wood-based products), accounting for the carbon absorbed during the growth of biomass (biogenic carbon) can make for an interesting challenge in interpreting the embodied impacts results. In simple words, these type of materials absorb the carbon during growth and lock it away safely in the product as installed in the building until the product is replaced or incinerated. Thus, here the carbon is a physical part of the product, and thus, is embodied in a "real" sense. This type of carbon is usually described as "sequestered" or "stored". It differs from the term "embodied GHG emissions" explained before, which is used in practice as a convention to express the impacts of a product at different stages of its life cycle.

Biogenic carbon emitted during the life cycle of the product should not be accounted as part of the total climate impact, as it is biologically based. It should be reported as separate information – please check section 7 dealing with the "indicators".

3. STATE OF STANDARDIZATION

On international and national level, a set of harmonized standards and methods for the assessment of embodied impacts, in parallel with other environmental indicators, exist on the different level of applications such as framework, building and product related. Specifically, in this guideline for construction product manufacturers, the standard ISO 21930 or EN 15804 is recommended to be used for the purposes of assessing embodied impacts as part of the total environmental performance of a construction product.

FIGURE 09 maps out all the existing international and national framework, building and product related standards, including also the standards focusing on the aspect of carbon footprint, such as the ISO/TS 14067, the Greenhouse Gas protocol, in the UK, the BSI PAS 2050 and 2060, in Switzerland the SIA 2032 or in Germany the VDI 4600. For more information, please check ST3 report link.

All these standards are based, in terms of the methodological principles and definitions, on ISO 14040 and ISO 14044 where LCA is defined as methodology to assess the products life cycle environmental performance.

The derived information on construction product is then used as a source of information for the overall assessment which can only be performed on the level of buildings (ISO 21931, ISO 21932 and EN 15978) or construction works, taking into account the functional and technical performance respectively.

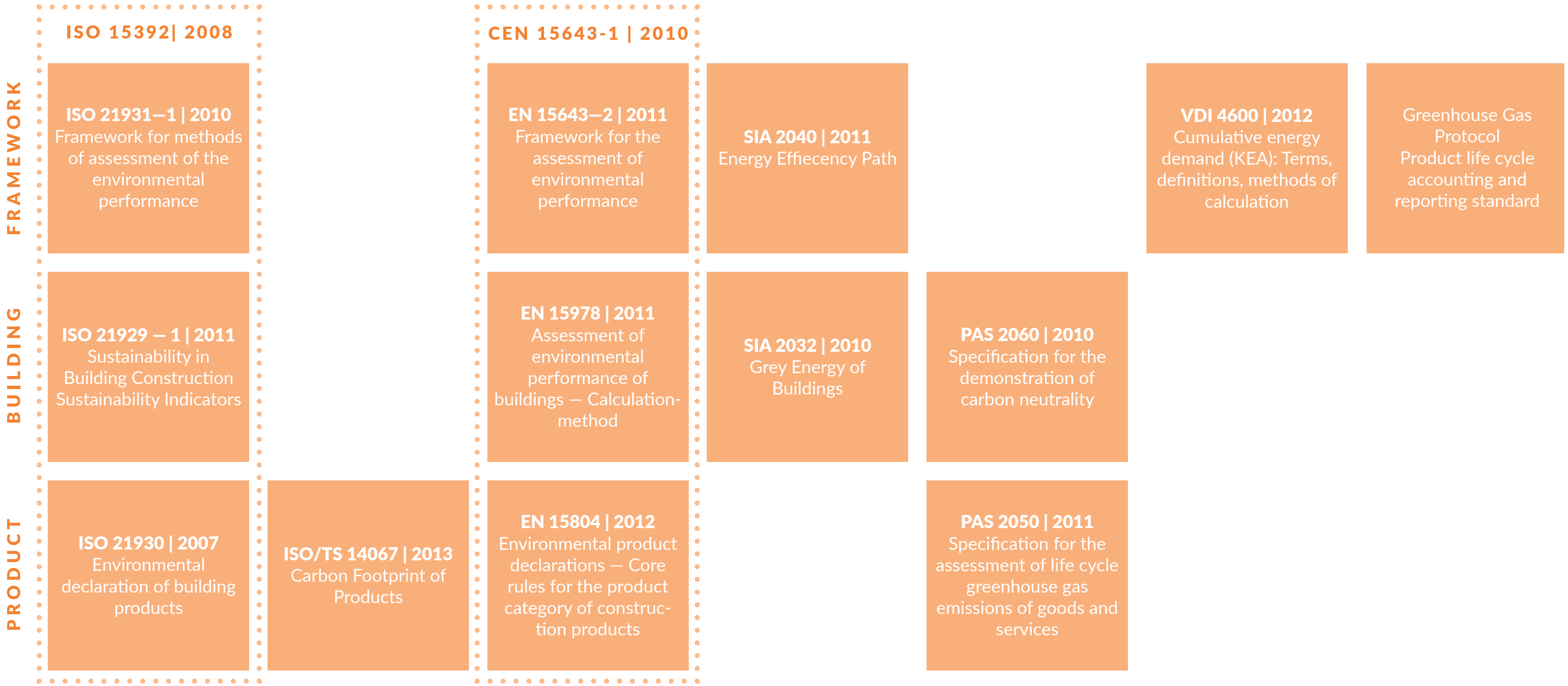


FIGURE 09 | MAPPING OF EXISTING STANDARDS RELATED TO THE CALCULATION & REPORTING OF EMBODIED ENERGY AND GHG EMISSIONS (SELECTED EXAMPLES)

4. IMPLICATIONS OF THE CHOICE OF OBJECT OF ASSESSMENT

In this guideline, the object of assessment (studied object) is only the construction product, meaning any item manufactured or processed for incorporation in construction works including both buildings and civil engineering works.

However, in industrial processes there may be a wide variety of different types of materials produced in conjunction with the intended product. In business vocabulary, these may be identified as co-products, intermediate products, non-core products or sub-products. In this document the term “co-product” is used. It is recommended to distinguish between co-products and products for the environmental impacts and aspects allocation. In a system analysis, every unit process has to be examined with respect to its co-products.

When dealing with systems involving multiple products and recycling processes, allocation should be avoided as far as possible, e.g. through process subdivision (disaggregation of multifunctional processes or facilities to isolate the input flows directly associated with each process or facility output) or system expansion (by including additional functions related to the co-products) where possible. If allocation is unavoidable (e.g. in situations where unit processes cannot be subdivided with certainty and the interdependencies between the product and co-products or waste are strong), it should be considered carefully, and should be justified. Specific rules are given in the standards ISO14040 series and EN 15804 respectively. Subsequently, the allocation formula can be determined by the manufacturer or by the experts acting on his behalf. An allocation can be made on the basis of volume, mass, price, etc. In general, the allocation problem for energy and mass flow or emissions in relation to co-products is parallel to the cost allocation problem.

In **FIGURE 10**, a decision tree is provided to facilitate the decision-making process of manufacturers in terms of which direction to follow in the allocation problem in case of additional co-production.

Besides the energy and material flows of the manufacturing processes, there are also material and energy flows associated with indirect processes (please check the section "selection and description of the system boundaries"). Which of these processes will be allocated to the main product and which one to the resulting co-products is also a matter of question.

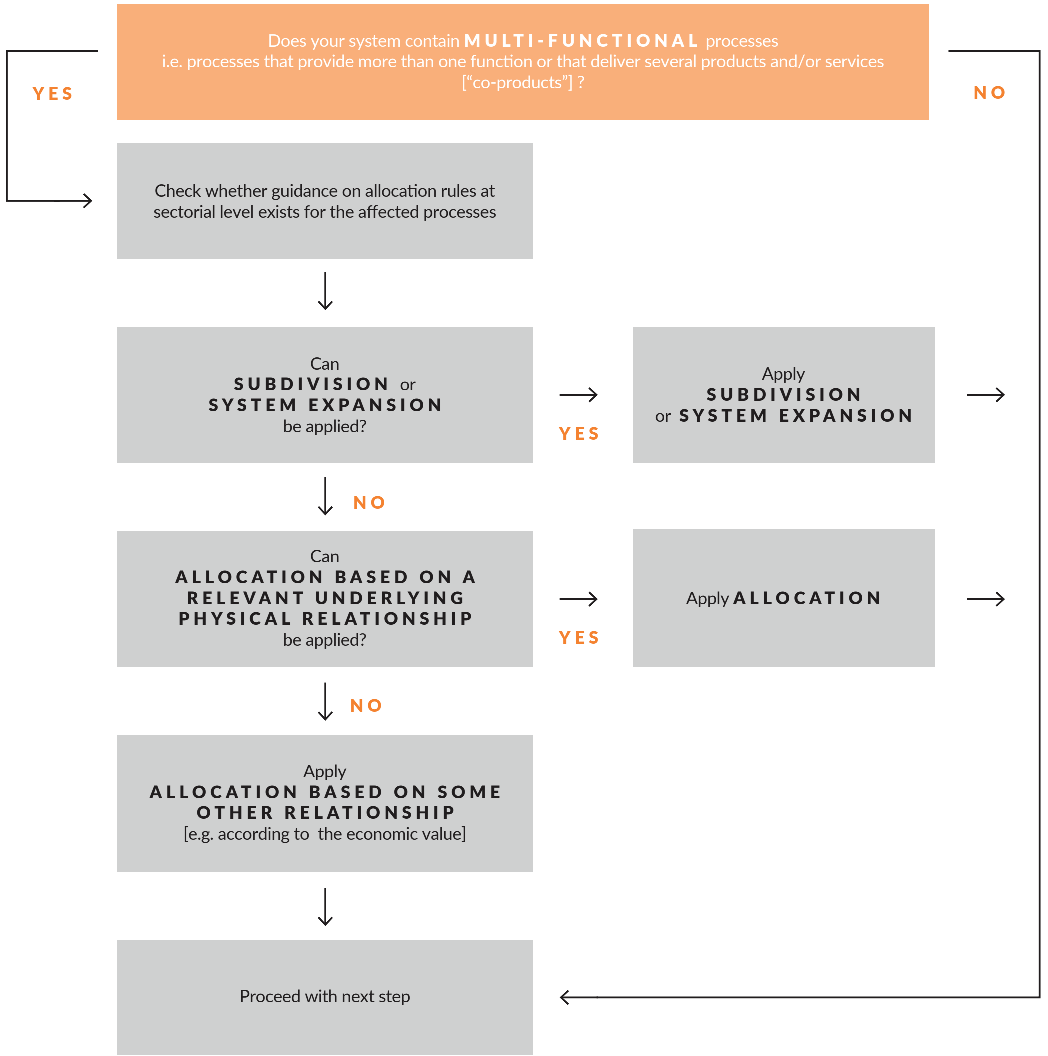


FIGURE 10 | DECISION TREE CONCERNING THE ALLOCATION PROBLEM

The allocation should follow the "polluter pays principle", if possible.

The quantified functional and technical performance of the object of assessment (product) is represented by the functional unit (a precise definition can be found in ISO 14040:2006 and other related standards). The **functional unit** is the unit of scale or reference on which the embodied impacts results are based, and relates to the given function of the product. In other cases, the functional unit should be defined according to the future use of the product as part of a building or construction work. This is used as the basis for comparison of similar products, and therefore, it is important to be clearly defined.

At a minimum, a functional unit should be comprised of a function (e.g. used in external walls), a quantity (e.g. 1 m^2), a duration (e.g. a specific service life under defined in-use conditions) and a quality (e.g. a specific thermal resistance or other technical characteristics).

E.g. for an acoustical ceiling panel: One square meter of ceiling panel for use for 50 years with specific performance attributes (e.g. NRC: 0.55-0.79, CAC: 35-40 and LR: 0.83-0.84).

Cases where the declared unit may be used instead of a functional unit are when:

» the precise function of the product at the building level is not known; there are products that can be used in a wide variety of different or similar functions in the building or construction works.
» the product is used as an input to another product and is not a ready-to-install product in the building; For raw materials (e.g. cement, gravel) a functional unit does not really make sense.
» the manufacturer does not intend to cover the full life cycle (since the information to describe post-gate life cycle stage would originate from the building)

Examples of declared units include:

» by item, e.g. 1 brick, 1 window (dimensions to be specified), 1 radiator;
» by mass, e.g. 1 kg of cement;
» by length, e.g. 1 m of pipe, 1 m of a beam (dimensions must be specified);
» by area, e.g. 1 m^2 of wall elements, 1 m^2 of roof elements (dimensions must be specified);
» by volume, e.g. 1 m^3 of timber, 1 m^3 of ready-mixed concrete.

In this context the definition of "service life" is also important; The term "service life" defined by manufacturers, describes how long the product's performance will continue meeting its initial requirements if a particular set of in-use conditions is assumed. More detailed definitions can be found in the ISO 15686 series. Service life depends on many parameters and is one subject of the ISO 15686 series. Some examples of these parameters are:

» declared product properties (at the gate) and those of any finishes;
» design application parameters (if instructed by the manufacturer), including references to any appropriate requirements;
» an assumed quality of work, when installed in accordance with the manufacturer's instructions;
» external environment, (for outdoor applications), e.g. weathering, pollutants, UV and wind exposure, building orientation, shading, temperature;
» internal environment (for indoor applications), e.g. temperature, moisture, chemical exposure;
» usage conditions, e.g. frequency of use, mechanical exposure;

» maintenance, e.g. required frequency, type and quality and replacement of replaceable components.

Thus, information regarding the service life of a product should always be accompanied by an installation scenario.

It is important to note that the provision of information concerning the service life of a product is essential regarding an assessment at a building level.

General Remark: For enterprises operating more than one manufacturing facility within a country (thus, operating in multiple locations and possibly with different manufacturing methods) for producing the same type of product, the following options exist:

» to conduct the embodied impacts assessment on the product, assuming that it is produced by a specific manufacturing facility (choice of one manufacturing site as the basis of the assessment)
» or to conduct the assessment on the product, assuming that it is an "average product" produced by the "average" manufacturing facility of this enterprise.

Here, the second approach is recommended to be followed. However, in cases where the enterprise operates in more than one country, the interrelationships between the different locations become more complex; the consultation with a specialist is advised.

5. MODELLING OF THE PRODUCT LIFE CYCLE

For the process and LCI respectively it is important to transform the product life cycle into a physical model and subdivide this into life cycle stages. There is already an established physical model in the form of a modular setup first developed by the international ISO/ TC 59/ SC 17 group in ISO 21930:2007 (the publication of second edition is expected soon) and later adopted by the European CEN/TC 350 group in EN 15804:2012 (the setup is alike for construction products and buildings). According to this model the product life cycle is divided in four life cycle stages and a number of information modules, see **FIGURE 11.**

These life cycle stages describe the entire life cycle of any construction product.

Specifically, the four life cycle stages are the following:

» Product stage (modules A1-A3)
» Construction stage (modules A4 and A5)
» Use stage (modules B1-B7)
» End-of-life stage (modules C1-C4)

As a supplement, the information module D may be added, and addresses potential benefits and loads beyond the discard products end-of-life (i.e. beyond system boundary). Module D deals with material related potentials in "future" e.g. reuse, recovery or recycling potential and its environmental consequences.

FIGURE 11 gives an overview of the modular approach for the description of the product-related life cycle information. Additionally, a distinction between embodied and operational impacts is highlighted.

The modular approach allows easy organisation and expression of data packages throughout the life cycle of the product. Thus, it is recommended to adopt the model described in international standardization and adapt this if needed to other models described in regional or national standards.

In general, this approach requires that the product system boundaries for the life cycle stages and the information modules included are transparent, well defined and applicable to the described product. More detailed information is given in the section "selection and description of system boundaries".

The main task for the manufacturer is the assessment of the module A3 — Manufacturing. This module lies in the full responsibility of the construction product manufacturer. However, the modules A1 – Raw material supply and related transport to the manufactuter (A2) form the basis for every "cradle to gate" assessment at the product stage.

Especially in the use stage (B1) a release of GHG-relevant emissions can occur and need to be reported in this module.

At this point, it is also important to make a distinction between the different use stage modules - maintenance, repair, replacement and refurbishment (B2-5). These modules cover the impacts related to the

Modular setup for the description of the life cycle information | **Additional info**

Stage	Module	Description	Embodied impacts	Operational impacts
PRODUCT STAGE	A1	Raw material supply	✓	
	A2	Transport	✓	
	A3	Manufacturing	✓	
CONSTRUCTION PROCESS STAGE	A4	Transport	✓	
	A5	Construction – installation process	✓	
USE STAGE	B1	Use, installed products	✓	
	B2	Maintenance	✓	
	B3	Repair	✓	
	B4	Replacement	✓	
	B5	Refurbishment	[✓]	
	B6	Operational energy use		✓
	B7	Operational water use		✓
END OF LIFE STAGE	C1	Deconstruction	✓	
	C2	Transport	✓	
	C3	Waste processing	✓	
	C4	Disposal	✓	
POTENTIAL BENEFITS & LOADS (Additional info)	*D*	Recovery, reuse, recycling potential	[✓]	

FIGURE 11 | MODULAR APPROACH FOR THE DESCRIPTION OF THE PRODUCT-RELATED LIFE CYCLE INFORMATION ACCORDING TO EN 15804:2012 & DISTINCTION BETWEEN EMBODIED AND OPERATIONAL IMPACTS.

service life of the building parts and components covering the full spectrum of possible activities; from a small maintenance activity to an important retrofit. It is sometimes difficult to determine which module a specific operation should be attributed to. If it is unclear whether an activity should be considered as maintenance, repair, replacement or refurbishment, the manufacturer should choose the most suitable module and provide a justification for this.

As the distinction between Modules B2 to B5 is not straightforward, it is recommended that the following principles are applied:

Maintenance should encompass all planned actions related to maintaining a product or building part, such as preventive and regular maintenance operations and cleaning operations. Maintenance should be understood as the set of context-related operations performed under normal conditions (e.g. a product could have different maintenance requirements in different climates).

Repair should encompass product modification and operations caused by accidents, improper installation or handling, unforeseeable events, etc. This includes, for example, corrective maintenance such as the replacement of a broken component or part due to damage (e.g. a window with broken glass). Repair module may also apply to complex systems consisting of components, whose service life is shorter than the overall product system.

Replacement should encompass the operations related to the replacement of the entire product due to damage (it does not meet its initial performance requirements) at the end of its life (replacement of the whole functional unit by a new one after RSL).

Refurbishment should encompass the operations related to replacement of a whole construction element as part of a concerted program of maintenance, repair and/or replacement for the building. Please note that refurbishment module is mostly related to the building level, rather than the product level. Thus, the module can be omitted when calculating the embodied impacts at a product level (in brackets in **FIGURE 11**).

Please note that B6 & B7 are only relevant for building integrated technical systems, e.g. technical equipment supporting operation of a building or construction works. Their characteristics in terms of how they influence the operational energy and water efficiency are part of the description of the product

6. THE PERSPECTIVE OF UPSTREAM AND DOWNSTREAM PROCESSES

The group of construction product manufacturers is diverse – from single parts/material manufacturers (dealing with the mining and materials manufacturing/one location) to “end-use” products manufacturers (product mix/multiple locations). There are differences in their approach for calculating embodied impacts. Thus, operations and structures can vary significantly. In order for an enterprise to assess the impacts across its operations, it must identify the boundaries it will work within and the processes over which the manufacturer has an influence over.

The manufacturers’ main responsibility is to describe their own/corporate processes (e.g. fuel and material use, as well as pollution, due to the manufacturing equipment and processes) in more detail as possible. This will give the opportunity to identify the key “hot spots” (the processes that make major contributions to the impacts) in the supply chain. Over these processes the manufacturer has an influence, so he can start the quantification and assessment of the embodied impacts for products by first calculating the on-site impacts of product manufacturing, the so-called gate to gate impacts (**FIGURE 12**).

Every activity carried out before the manufacturing process in the supply chain belongs to the upstream processes. Although the manufacturer has no influence over these processes, he can influence indirectly the upstream processes by asking lower-impact materials and/or energy sources inputs to make the product (pressure backwards in the supply chain for improved processes) (**FIGURE 12**).

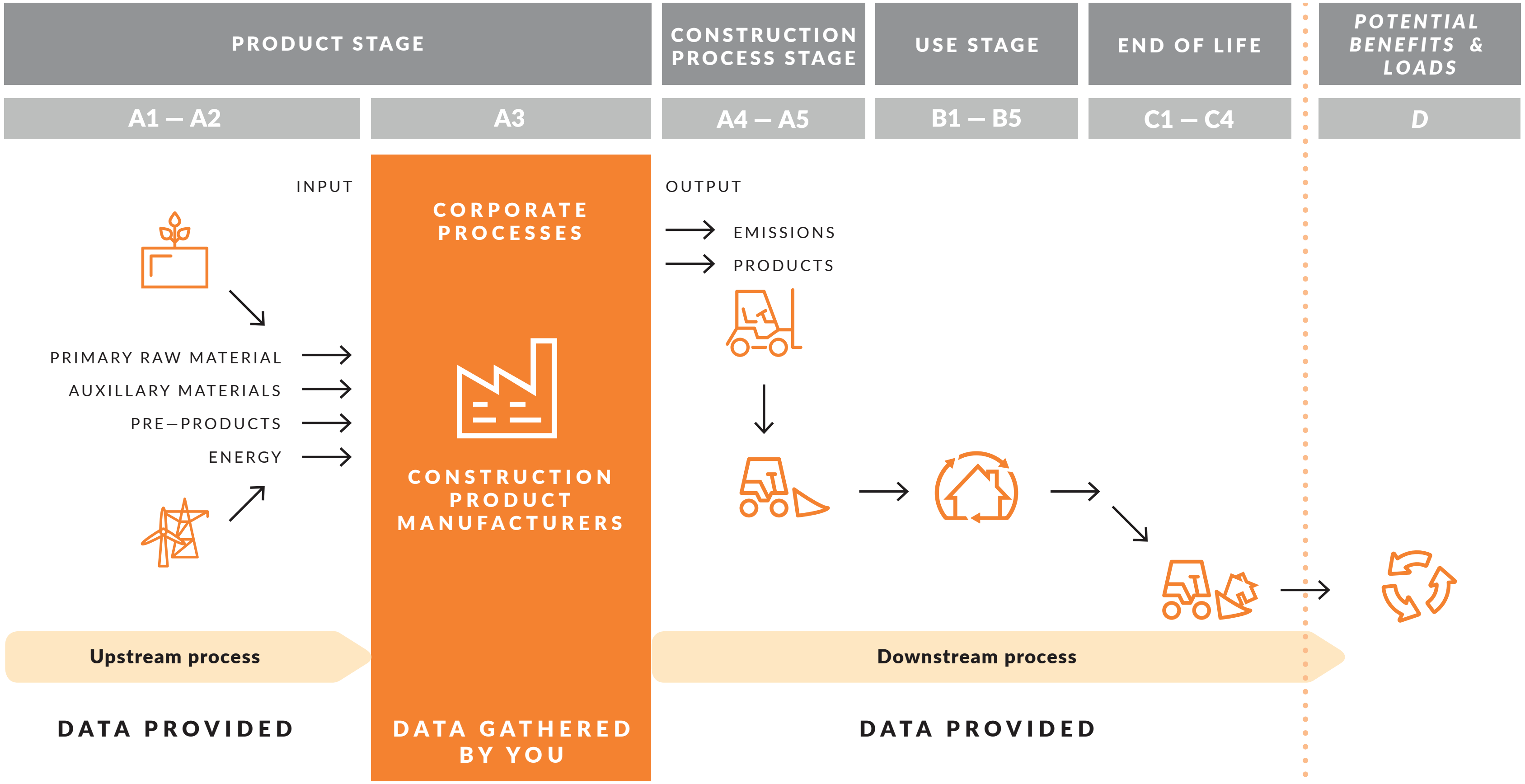


FIGURE 12 | DATA COLLECTION AND PROVISION IN THE SUPPLY CHAIN OF A CONSTRUCTION PRODUCT. THE SUPPLY CHAIN IS DIVIDED INTO UPSTREAM, CORPORATE AND DOWNSTREAM PROCESSES.

After looking on site and upstream, it is time for the manufacturer to look downstream (**FIGURE 12**), at the processes occurring once the product leaves the factory. Downstream life cycle stages include the transport and construction process, the use stage and end-of-life management. Manufacturers have no direct influence over the life cycle of their products after their delivery. What they can do is to provide information on what are the impacts of their products under specific conditions of use (based on different scenarios).

In case the manufacturer has established a take-back system, he might have an influence also over the recycling processes. By taking increasing responsibility for the end-of-life management of the products the manufacturer produces and designs them in such a way to be reused or recycled in his own facilities, the enterprise reduces the need for new materials in production and creates a tight “inner circle” allowing the use of less material, labor, energy, and capital.

In this way, the manufacturer can contribute to the transition towards a circular economy with a focus on reuse and recycling.

All these steps are further analysed in the section “Collection, Processing and Presentation of Information on Individual Life Cycle Stages”

7. THE INDICATORS

For the quantification and assessment of the embodied impacts resulting from all these processes described in **FIGURE 11** appropriate indicators are needed. These should be easy to understand, transparent and easy to interpret, but also these must be able to be determined within a reasonable amount of time and cost. Here, it is recommended that the following indicators represent the quantified embodied impacts of construction products (**TABLE 02**):

TABLE O2 | RECOMMENDED INDICATORS FOR THE QUANTIFICATION AND ASSESSMENT OF EMBODIED IMPACTS

	CORE LIST OF INDICATORS	ADDITIONAL INDICATORS
Embodied Energy [MJ]	EE1 - Consumption of primary energy fossil [PEf]	Consumption of fossil fuels as feedstock
	EE2 - Consumption of primary energy non renewable [PEnr]	
	EE3 - Consumption of primary energy total (renewable + non-renewable) [PE_t]	Consumption of biomass as feedstock
Embodied GHG Emissions [$kgCO_2eq.$]	EG1 - Global Warming Potential [GWP 100]	F-gasses as identified in Montreal Protocol Stored Carbon

Thus, the use of three different indicators is suggested here for embodied energy quantification (EE1, EE2 and EE3) and one indicator for embodied GHG emissions quantification (EG1).

However, it should be noted that different sources of energy can be included in the recommended indicators quantifying embodied energy, as well as different GHG emissions can be included in the $kgCO_2eq$.

Therefore, a clear statement is needed in order to determine the exact character and scope of each indicator and allow comparisons between data. **TABLE 03** is an example of the parameters that need to be given for describing the character of each of the recommended indicators in a transparent way – specifically, Primary Energy total (PE_t) and Global Warming Potential (GWP) are described here. The exact description of the different indicators as recommended by Annex 57 is given in the detailed report “ST1 report” that can be found here: www.annex57.org

TABLE O3 | EXAMPLE OF A WAY OF DEFINING THE CHARACTER OF THE INDICATORS USED FOR THE QUANTIFICATION OF EMBODIED IMPACTS

CHARACTER OF THE INDICATOR PE_t	
Included non-renewable energy resources	Fossil fuels as energy Fossil fuels as feedstock (separately reported) Nuclear fuels
Included renewable energy resources	Biomass Biomass as feedstock (separately reported) Solar energy Geothermal energy Hydropower Wind power
Type of system boundary	Cradle to Grave (+ Module D if considered appropriate; to be reported separately)
Unit of measurement	MJ/functional unit (or declared unit)

CHARACTER OF THE INDICATOR GWP	
Type of GHG emissions	Fuel related Non fuel related – process related emissions Non fuel related – F-gasses (separately reported)
Type of system boundary	Cradle to Grave + Module D (only as information)
Unit of measurement	$kgCO_2eq$ /functional unit (or declared unit)
Included GHG emissions in CO_2eq	GHGs as identified in the 5th IPCC report Freon gases as defined in Montreal protocol

For the manufacturers wishing to declare the impacts of their products in the form of an EPD, the connection of the indicators recommended here with ones indicated in the EPD- related ISO standard and EN standard is shown in **TABLE 04**.

TABLE O4 | THE LINKAGE OF THE RECOMMENDED INDICATORS (TABLE 02) WITH THE RESPECTIVE ONES INDICATED IN ISO 21930 AND EN 15804

INDICATORS	ISO 21930 | 2007	EN 15804 | 2012
Consumption of primary energy fossil [PEf]	Not included in this version (ADP_fossil to be included in the revised version)	Abiotic depletion potential (ADP_fossil fuels) for fossil resources
Consumption of primary energy non renewable [PEnr]	Non-renewable primary energy used as an energy carrier (fuel) $NRPE_E$	Use of non renewable primary energy excluding non renewable primary energy resources used as raw materials

INDICATORS	ISO 21930 | 2007	EN 15804 | 2012
Consumption of primary energy total (renewable + non-renewable) [PE_t]	Two indicators are added up: » Non-renewable primary energy used as an energy carrier (fuel) $NRPE_E$ » Renewable primary energy used as an energy carrier (fuel) RPE_E	Two indicators are added up: » Use of non renewable primary energy excluding non renewable primary energy resources used as raw materials » Use of renewable primary energy excluding renewable primary energy resources used as raw materials
Global Warming Potential [GWP 100]	Global Warming Potential, GWP	Global Warming Potential, GWP
Consumption of fossil fuels as feedstock	Non-renewable primary energy used as material $NRPE_M$	Use of non renewable primary energy resources used as raw materials
Consumption of biomass as feedstock	Renewable primary energy used as material RPE_M	Use of renewable primary energy resources used as raw materials
F-gasses as identified in Montreal Protocol	It is not identified as a separate indicator	It is not identified as a separate indicator
Stored Carbon	It is not identified as a separate indicator in this version (but to be included in the revised version)	It is not identified as a separate indicator
Stored Carbon	It is not identified as a separate indicator in this version (but to be included in the revised version)	It is not identified as a separate indicator

8. AVAILABLE DATA SOURCES

Different types of data are needed for the embodied impacts quantification. Initially, within manufacturer's responsibility falls generation of:

» Technical data (description of the product and its technical characteristics/functional unit)
» Data on energy and raw materials/ pre-products demand for manufacturing of the final product (calculation based on the description of the manufacturing process)

Manufacturers need data from third parties for the processes on which they have no influence over (upstream and downstream processes). Different data sources are:

» LCA data or EPD's from the energy supplier and the various primary product suppliers. The manufacturer should develop an evaluation and acceptance procedure for energy sources, raw materials and pre-products.
» Generic databases (DB) (either national or commercial) that include environmental information on different energy supply sources and primary products.

Please note that there are also sector- or branch-EPDs (or sector specific LCA data in other forms) produced by industry associations that provide average data of several manufacturers of the same product type. These can be used as a benchmark for a construction product targeting improvements – an indication of whether a product's performance is above average or below average compared to the average performance. Sector EPDs may also be used by manufacturers/ procurers as orientation (as a reference) for the general environmental performance of a product category when they ask for product-specific EPDs from their energy and materials suppliers (basis for acceptation).

PART 03 – STEPWISE QUANTIFICATION AND ASSESSMENT PROCESS OF EMBODIED IMPACTS

Below a systematic approach for the construction products' embodied impact quantification is presented and discussed.

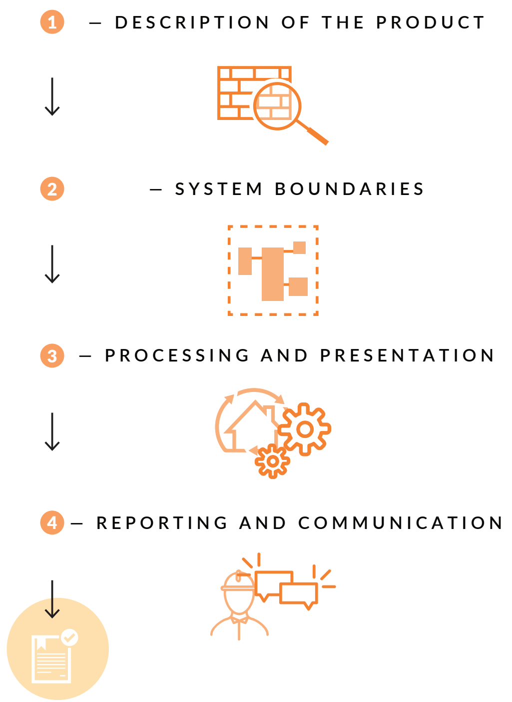


FIGURE 13 | STEPWISE QUANTIFICATION

1. DESCRIPTION OF THE PRODUCT

The starting point in the quantification of embodied impacts is the description of the object of assessment – in this context the construction product. Specific product information that should be included is:

» exact product designation
» name of the manufacturer
» an assignment to a product group
» typical unit of quantity
» indications on delivery forms
» indications on relevant transport-related characteristics
» information on relevant storage-related characteristics
» technical characteristics and properties
» service life under defined conditions of use
» information regarding the intended use
» information on the efficiency or energy consumption in the use phase (if applicable)
» information on the flow rate of water or water consumption in the use phase (if applicable)
» information on emissions into the ambient air during the use phase
» information on emissions into the soil or in water during the use phase

For information without a further reference to the product's behaviour in the life cycle a "declared unit" is used as a reference unit, while for information with a further reference to the product's life cycle a "functional unit" is used as a reference – please check the relevant section in "implications of the choice of the object of assessment".

2. SELECTION AND DESCRIPTION OF THE SYSTEM BOUNDARIES

The information on embodied impacts of a product may cover different combinations of modules i.e. cover different life cycle stages or parts thereof. Where possible embodied impacts from all life cycle stages should be considered (Cradle to Grave approach – see **FIGURE 14**); if this is not possible, the system boundary Cradle to Gate should be used at the minimum, as it represents the mandatory requirement for EPDs. Specifically, it covers the mandatory production stage that is divided into the information modules extraction and upstream production (raw material supply), transport to factory and manufacturing. Modules beyond the gate are based on scenarios.

In general, the results should be reported based on a declared unit, if the following system boundaries are selected: cradle to gate, cradle to site or cradle to handover. In all the other cases, the results should be reported based on the functional unit.

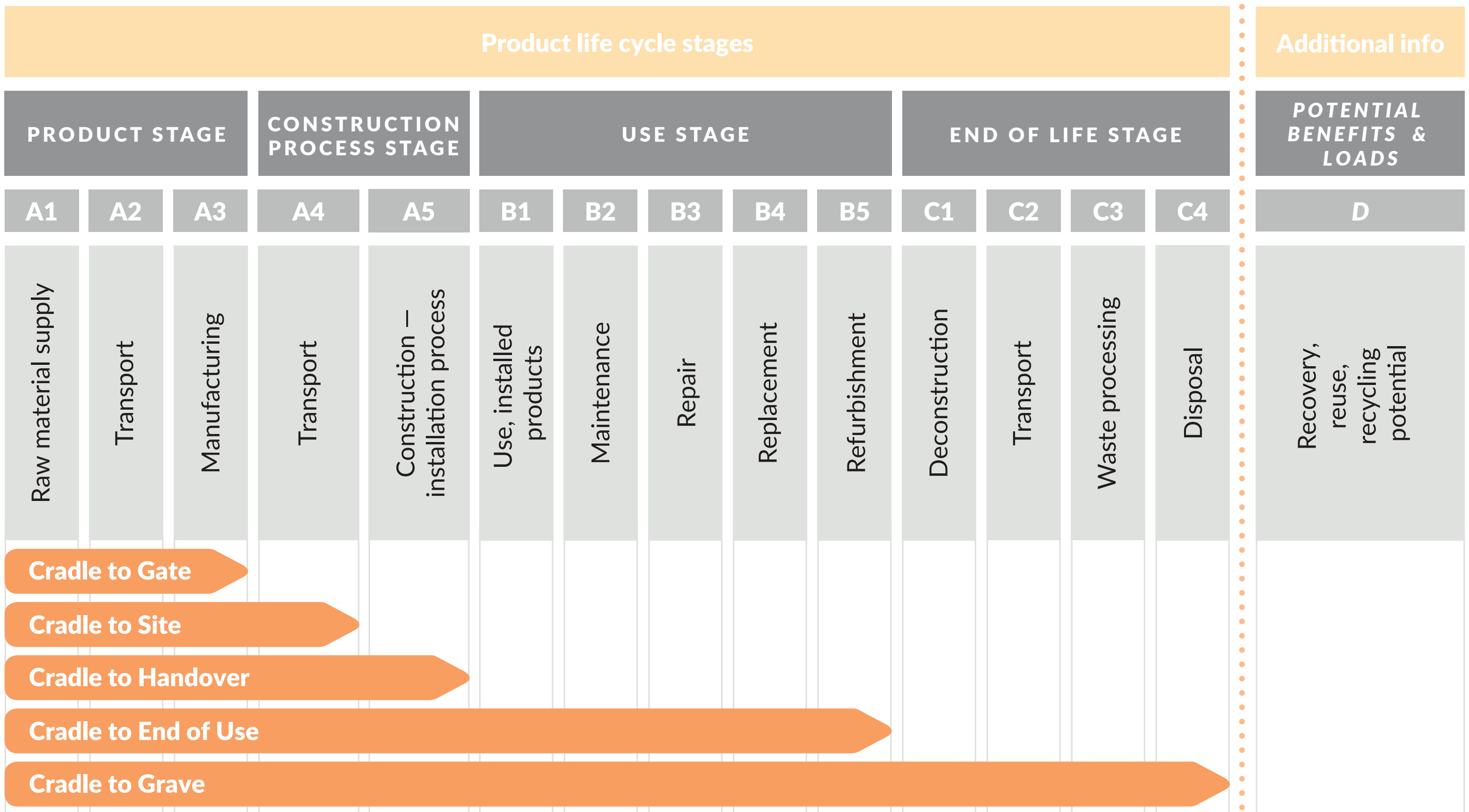


FIGURE 14 | ILLUSTRATION OF THE DIFFERENT TYPES OF SYSTEM BOUNDARIES AND THE PRODUCT LIFE CYCLE STAGES INCLUDED IN EACH SYSTEM BOUNDARY USING THE RESPECTIVE MODULES OF BUILDING LIFE CYCLE MODEL DEVELOPED BY THE GROUP CEN TC 350 (EN 15804:2012), (BASED ON BALOUKTSI & LÜTZKENDORF, ANNEX 57 ST1 REPORT)

FIGURE 14 provides an overview of which processes/modules are included in each system boundary type specifically in terms of embodied impacts. More information on the different system boundary types is given in the detailed report "Basics, Actors and Concepts" that can be found here: www.annex57.org

The net benefits and impacts beyond the system boundary (e.g. savings accruing to a second user from recycled steel use) may be quantified and if so they shall be reported separately as additional information in module D.

Please note that some service, material, and energy flows are not directly connected to the studied product (referred to as "indirect" processes here) during its lifecycle because they do not become the product, make the product, or directly carry the product through its life cycle. More information on how to deal with these processes is given in the next section. Examples include service, material, and energy flows due to:

» Overhead operations (e.g., facility lighting, air conditioning)
» Corporate activities and services (e.g., research and development, administrative functions, company sales and marketing)
» Capital goods (e.g., machinery, trucks, infrastructure)

Once the product has been described (the functional unit clearly defined), and the system boundary on which the calculation and assessment of embodied impacts will be based are selected, all of the material and energy "flows" in and out of the product system should be identified and mapped as they are used to make and distribute the product.

The process map is a schematic drawing of all the material and energy flows in the life cycle stages of the product being assessed. A process map is useful to communicate in a visual way what has been included and excluded from the analysis.

The process map can be simple or detailed as deemed necessary or as time permits. It is recommended to focus on the most important aspects (e.g. heaviest materials, key energy flows) first, to avoid unnecessary detail. If necessary, the map can always be expanded. It is recommended that an enterprise should create a detailed process map for internal use and assurance, as basis for data collection.

TABLE O5 | DEVELOPMENT OF A PROCESS MAP – CRADLE TO GATE

LIFE CYCLE STAGE	BRAINSTORM PROCESS MAP	REFINE PROCESS MAP THROUGH QUESTIONS
Materials Supply	What are the raw materials that make up your product (including packaging)?	Weight and composition of raw materials and packaging of your product? Waste types and waste management of wastes arising from incoming raw materials and packaging (i.e. are raw materials packaged?). Waste rate of incoming raw materials and packaging (i.e. quality rejects, breakage, etc...)?
Transport/ logistics	Which companies supply these raw materials?	Location of raw material and packaging suppliers? Method of distribution of raw materials and packaging distributed to production facilities (transport mode, distance)?
Production Process	Which manufacturing processes are undertaken to make or assemble your product? Which types of energy sources are used to make or assemble your product: electricity, natural gas, fuel oil, etc? Identify where waste arises throughout the production process	Do you purchase or generate your own electricity? For purchased fuels, have you included these within your raw material supply list? Can waste arising per unit of product studied be allocated? Any significant indirect processes that should be included (i.e. cleaning chemicals, heating or cooling manufacturing area, refrigerant leakage, etc.)? Any significant process emissions which should be included (i.e. decarbonisation of limestone)? Any significant carbon sequestration during manufacturing of the product?

According to the British Standards Institute (BSI) there are questions that can be asked when completing a process map which will enable a more detailed process map to be developed (see **TABLE 05** as an example).

For the gate-to gate impacts (production process) the inclusion of the indirect processes in the assessment should be clearly stated. In this guideline, it is recommended that the energy and material flows in relation to:

» overhead operations should be always included in an assessment; the use of reasonable allocation rules to the allocation of these processes to the output product and co-products is necessary here.

» capital goods should be included, as far as this is possible and relevant. If included, the type and extent of their inclusion should be reported separately. For an allocation to the products and co-products, the use of appropriate allocation rules is necessary.

» possible energy and material inputs for research, development or marketing processes should not be included, unless they are already included as part of the overhead processes (power consumption of a research department on the factory premises). However, if included, this should be reported separately.

3. COLLECTION, PROCESSING AND PRESENTATION OF INFORMATION ON INDIVIDUAL LIFE CYCLE STAGES

The development, preparation and publication of information and data must be oriented towards satisfying the information needs of stakeholders along the value chain, the information needs of the company itself to support the improvement of its own products and corporate processes, as well as towards being in line with the state of international, national and regional (for example, EU) standards.

For the construction products information the complete life cycle is required. It is useful to divide this information into life cycle stages and to assign "information modules" to these stages. As mentioned before, ISO 21930 provides an internationally recognized procedure for the division of construction products' life cycle into modules.

A step-by-step approach is recommended for embodied impact calculation. The calculation can be divided into the following steps:

a. Accounting of the direct and indirect energy and material flows within the company (A3)
b. Accounting of the energy and material flows for upstream processes including transport (A1-2)
c. Summary of a) & b) to form "cradle to gate" information (A1-3) – including a first analysis of the situation
d. Preparation of information on the processing possibilities on site (A4-A5) – including an analysis of the situation
e. Preparation of information on the direct use of the product in terms of any emissions into environment (B1)
f. Preparation of information on cleaning, servicing and maintenance (B2)
g. Preparation of information on repair (B3)
h. Preparation of information on replacement (B4)
i. Preparation of information on future modernization/refurbishment (B5)
j. Preparation of information on deconstruction (C1)
k. Preparation of information on disposal (C2-C4)
l. Preparation of information on potential benefits and loads beyond the discard products end-of-life (D)

For a more detailed analysis of each step, please check the analysis below:

A) Accounting of the direct and indirect energy and material flows within the company (A3)

In this step, the manufacturer should make use of the process chain configurations and analysis as part of the development of the product's process map as described earlier and focus on the energy and material flows occurring within the company. The direct manufacturing processes within the enterprise (all direct inputs and outputs attributable to the processes at the production facility) for major products, and possibly also for co-products, should first be taken into account in the calculation process. These include:

» type and quantity of raw and ancillary materials and pre-products used as inputs for the manufacturing of the final product
» type and amount of energy (resources) consumed for the manufacturing processes
» type and amount of secondary energy (resources) consumed for the

manufacturing processes

- type and quantity of process-related emissions (especially GHG) — this is usually specified on the basis of calculations, and not of measurements
- type and quantity of waste leaving the site/enterprise

Please note that in case of a co-production, a reasonable allocation formula must be selected. When the product manufacturing is realised at several locations average values may be generated. Please for more information go to the section "Implications of the choice of the object of assessment"

Secondly, it should be considered whether there are important processes not directly connected to the studied product (i.e. management, storage, internal transport for the different sites, heating of manufacturing halls, etc.) that need to be accounted for with respect to their consumption of energy resources or energy (as described in the section "development of a process map for the product"). By using meaningful allocation rules, the energy and material flows of such processes can be allocated to primary and secondary processes of actual production of the product.

B) Accounting of energy and material flows for upstream processes including transport (A1-2)

In this step, the supply relationships between the supplying companies and the manufacturer must be clarified. Questions that should be answered by the manufacturer are:

- From which energy supplier the manufacturer buys energy?
- From which material supplier the primary products or raw materials are purchased?
- What means of transport have been used for the transport of raw materials up to the factory gate and what are the transport distances?

Preferably, the provision of data on the primary energy consumption and the associated GHG emissions from all the suppliers of energy and primary products to the manufacturer should be realised on a contractually agreed basis.

C) Summary of the data accounted for in A) & B) to form "cradle to gate" information (A1-3) – including a first analysis of the situation

In this step, the information on the type and quantity of energy and raw materials/pre-products required for the manufacturing process identified in A3 is combined with respective energy and emission factors/intensities that can be either process-related (e.g. kgCO_2eq./kWh) or input-output-related (e.g. kgCO_2eq./€spent on electricity) - thus, with information on the amount of primary energy and associated GHG emissions related to the extraction/production of these materials/pre-products and energy sources. Preferably, this information should be requested from the materials and energy suppliers (gathered as part of the upstream processes in A1). If such data are not available directly from the suppliers, the following data sources can be used (for a more detailed analysis please check section "deciding which dataset to use"):

- publicly accessible databases or government publications
- licensed 3rd party databases
- Data from comparable products
- Industry publications or sector-EPDs

Please note that these information should be supplemented by information on process-related emissions (emissions due to chemical reactions in the production), if applicable.

Data on incoming freight transport (transport of materials to the factory gate) can be obtained from expenses claims, vehicle records, etc. Expenses claims can be directly associated with fuel costs and hence with fuel consumed. If vehicle types are known, average fuel use rates could be multiplied by known distances to obtain total fuel consumption.

However, it is difficult to determine the transport related impacts, if the products are sourced from intermediaries and not the real suppliers. The situation becomes even more complicated, if parts of raw materials or pre-products are imported from different parts of the world. In such a case, the assistance of a specialist (environmental consultant) is advisable.

A first important intermediate result can be achieved by linking the information on the primary energy consumption and associated GHG emissions assigned to each pre-product to the quantity of this pre-product used for the manufacturing of the final product. Thus, a first analysis to identify opportunities for optimization is here possible. At this stage, it can be determined what processes, fuels or pre-products influence significantly the energy and material flows and what are the opportunities and alternatives for optimization.

D) Preparation of information on the processing possibilities on site (A4-A5) – including an analysis of the situation

The optional information modules A4-A5 are dealing with the transport of the construction product to the building site and its installation into the building or civil engineering works. A more detailed description of these modules according to International and European standards can be:

» A4 – Transportation from the production gate to the construction site (including also transportation from the production gate to the central warehouse or storage site if relevant);
» A4 or A5 – Storage of products, including the provision of heating, cooling, humidity control, etc., if relevant; wastage of construction products (including additional production processes to compensate for the loss of wastage of products);
» A5 – Installation of the product into the building (or civil engineering works) including manufacture and transportation of ancillary materials and any energy or water required for installation or other on-site operations related to the product; waste processing of the waste from product packaging and product wastage during the construction processes up to the end-of-waste state or disposal of final residues.

TABLE O6 | TYPICAL INFORMATION REQUIREMENTS FOR THE DEVELOPMENT OF TRANSPORT AND INSTALLATION RELATED SCENARIOS

MODULES	INFORMATION REQUIRED FOR THE DEVELOPMENT OF SCENARIOS	WHAT IF THERE IS NO SPECIFIC DATA?
A4 Transport	» Information about the transport form (e.g. long distance truck, boat, etc.) » Vehicle load capacity kg or m^3 per vehicle » Bulk density of transported products kg/m^3 » Capacity utilisation (including empty returns) % » Fuel type and consumption litre of fuel type per distance » Transport distances in km	When specific data on these parameters are not available, generic datasets for transport (e.g. factors expressed per tonne-km) can be used (e.g. taking into account the typical vehicle size, fuel efficiency, typical loading, etc.), while for the transport distances average values can be used (e.g. based on national transport statistics). Impacts of waste that is created within the transport phase should be also considered.
A5 Construction/ Installation Process	» Ancilliary materials for the installation (specified by material) » Water use » Other resource use » Quantitative description of energy type and consumption during the preparation and installation process » Direct emissions to ambient air, soil and water	When specific data on these parameters are not available, generic data from e.g. construction firms can be obtained.

These information modules are prepared based on specified scenarios by the manufacturers (as it is the case for all downstream processes). In this sense, it is recommended for each module to indicate individual data/ information for different scenarios (please check **FIGURE 14** in section 05) – e.g. individual data for different possibilities/options of transport (A4) or installation (A5). Thus, several case specific modules (information packages) can be included in the same module based on the number of typical scenarios that can be identified by the manufacturer to support the development of the scenarios at building level. The information needed for the development of scenarios for A4-5 are presented in **TABLE 06.**

Please note that the provision of different installation scenarios presupposes the manufacturer has a clear idea on the different installation possibilities and technologies on-site. Consultation with different contractors may be of help here.

E) Preparation of information on direct use of the product in terms of any emissions to the environment (B1)

This module covers the embodied impacts connected to the normal (i.e. anticipated) use of products, not including those related to energy and water use, which are dealt with in B6 and B7 see **FIGURE 11**. One example, is the release of substances from the facade, roof, floor covering, walls and different surfaces (interior or exterior).

In terms of embodied impacts as defined here, this module applies mostly to two main categories of manufacturers:

» **Manufacturers producing foam insulation materials** (particularly extruded Polystyrene (XPS) and Spray Polyurethane Foam (SPF)): If the product contains F-gases (usually as blowing agents), these should be reported in B1, since they have the potential to be released during the use stage, but separately from the indicator

EG1 (additional indicator/information – please check section "indicators").

- **Manufacturers producing cooling systems** (chillers, commercial refrigerators, A/C systems, etc.) The same recommendation as above applies also here.

Please note that F-gases are powerful greenhouse gases, with a global warming effect up to 23 000 times greater than carbon dioxide (CO_2), and their emissions are rising strongly. Please take into account the current approaches to reduce impacts into the environment from future F-gases use (as a substance in the product).

Also note that the biotic carbon sink may be optionally reported (always as a separate information) in B1 as "x kg CO_2 bio stored for y years", if applicable to your product.

F) Preparation of information on cleaning, servicing and maintenance (B2)

This module applies only to construction products where predictable maintenance procedure exists; Examples of such product groups are:

- Flooring, where regular cleaning is required
- Products requiring regular surface maintenance, such as painting (e.g. windows, internal walls, ceilings, etc.)

Maintenance is part of the "intended use" definition that should be provided with a product's reference service life (RSL). The RSL is valid under a specific set of conditions, notably the in-use environment (e.g. UV, heat, humidity, etc.), and proper implementation and maintenance that comply with the producer's recommendations and with state-of the art practices.

Specifically, for maintenance, the impact for producing and transporting the materials used (A1-4 for cleaning agents), the impact of the maintenance activity (water and energy used) and the impact of disposing of any waste produced (e.g. waste water from cleaning) need to be considered. In cases, where there are significant variations among scenarios, it is more helpful to report these impacts not as a single process (aggregated), broken down and reported separately to allow alternative scenarios to be generated.

Maintenance processes should be considered on the basis of the most likely scenarios. The location and type of loading have a great influence on the maintenance requirements. Required information to specify these scenarios are presented in **TABLE 07**.

TABLE 07 | TYPICAL INFORMATION REQUIREMENTS FOR THE DEVELOPMENT OF MAINTENANCE RELATED SCENARIOS

MODULE	INFORMATION REQUIRED FOR THE DEVELOPMENT OF SCENARIOS
B2 Maintenance	» Maintenance process » Maintenance cycle (Number per RSL or year) » Ancillary materials for maintenance (e.g. cleaning agent, specify materials) in kg/cycle » Quantitative description of energy type and use during maintenance (e.g. vacuum cleaning), energy carrier type e.g. electricity, and amount, if applicable and relevant (kWh or MJ)

G) Preparation of information on repair (B3)

This module applies only to construction products where predictable repair procedure exists; Examples of such product groups are e.g.:

» Doors, windows
» HVAC systems

Specifically, this module may include the impact for producing and transporting the materials used (A1-4 for any component and ancillary products used for repairing), the impact of the repair activity (water and energy used) and the impact of disposing of any waste produced (e.g. removed parts) need to be considered. In cases, where there are significant variations among scenarios, it is more helpful to report these impacts not as a single process (aggregated), but broken down and reported separately to allow alternative scenarios to be generated.

Repair processes should be considered on the basis of the most likely scenarios. Required information to specify these scenarios are presented in **TABLE 08**.

TABLE 08 | TYPICAL INFORMATION REQUIREMENTS FOR THE DEVELOPMENT OF REPAIR RELATED SCENARIOS

MODULE	INFORMATION REQUIRED FOR THE DEVELOPMENT OF SCENARIOS
B3 Repair	» Inspection and repair process » Repair cycle (number per RSL or year) » Ancillary materials for repair (kg/cycle) » Quantitative description of energy type and use during repair (e.g. crane activity), energy carrier type e.g. electricity, and amount, if applicable and relevant (kWh or MJ) » Net fresh water consumption (m^3) » Direct emissions to ambient air, soil and water (kg) » Waste material resulting from repair; specified by type

H) Preparation of information on replacement (B4)

This module includes production and transportation impacts of the new product and packaging (A1-4 of the new product), all impacts due to the replacement process (A5 of the new product), the end of life stage of the original product (C1-4), as well as any waste from the installation of the replacement, packaging waste. If it is assumed by the manufacturer that the product design and production will not change in future (e.g. expected better production processes or use of better raw materials or pre-products), this means that the impacts already declared in modules (A1-5) can be given here as a first estimation of this module. The cradle to grave boundary has been chosen for the analysis in case also the impacts declared in (C1-4) can be added here.

The service life of a product or building component should always be provided with a maintenance scenario (and valid only under the conditions described with this scenario). Since it is recommended here to provide different maintenance scenarios (please check the relevant section), this means that also different service lives based on these scenarios should be provided.

The information required to specify the scenarios or to support the development scenarios of this module at the building level are similar to the information required for maintenance and repair.

I) Preparation of information on future modernisation/refurbishment (B5)

Usually this information module is only applicable to buildings. Separate information on embodied impacts (not part of this inventory) are required for products selected to be used for a building modernization. For the removal of the existing product the modules C and D can be applied in this context.

J) Preparation of information on deconstruction & demolition (C1)

When its service life has ended, the product is removed, either as part of a replacement, building refurbishment or building demolition. This module covers the deconstruction, including dismantling or demolition, of the product from the building and energy use for this work, including initial on-site material sorting.

To specify the deconstruction scenarios, information related to the collection process is required. This information needs to be reported by type (how many kg of product are collected separately and how many kg are collected with mixed construction waste?)

Please note that the deconstruction process may have similarities with the replacement process (B4).

K) Preparation of information on disposal (C2-C4)

The optional information modules C2-C4 are dealing with the transport of the discarded construction product either to the waste processing facility to prepare this for recycling or recovery, or to the landfill for its final disposal. A more detailed description of these modules according to international and European standards can be:

» C2 – transportation of the discarded construction product as part of the waste processing, e.g. to a recycling site and transportation of waste e.g. to final disposal;
» C3 – waste processing e.g. collection of waste fractions from the deconstruction and waste processing of material flows intended for reuse, recycling and energy recovery. Waste processing shall be modelled and the elementary flows shall be included in the inventory. Materials for energy recovery (only when materials have reached the end-of-waste-state can they be considered as materials for energy recovery) are identified based on the efficiency of energy recovery with a rate higher than 60 % without prejudice to existing legislation. Materials from which energy is recovered with an efficiency rate below 60% are not considered materials for energy recovery.
» C4 – waste disposal including physical pre-treatment and management of the disposal site.

Please note that for some products, also after having reached the “end-of-waste” state, further processing may also be necessary in order to replace primary material or fuel input in another product system. Such processes are considered to be beyond the system boundary and are assigned to stage D – see next section.

All these modules should be considered on the basis of the most likely scenarios (an investigation of national waste legislation and statistics is important here). Required information to specify these scenarios are presented in **TABLE 09.**

TABLE O9 | TYPICAL INFORMATION REQUIREMENTS FOR THE DEVELOPMENT OF WASTE PROCESSING AND DISPOSAL RELATED SCENARIOS

MODULES	INFORMATION REQUIRED FOR THE DEVELOPMENT OF SCENARIOS	WHAT IF THERE IS NO SPECIFIC DATA?
C3 Waste Processing	» Potential future recycling (kg for reuse, kg for material recycling, kg for energy recovery) » Description on current practice of reuse » Description on current practice of material recycling » Description on current practice of energy recovery	When specific data on these parameters are not available, generic data from e.g. contractors and firms dealing with deconstruction and waste management activities can be obtained.
C4 Waste Disposal	» Disposal specified by type (kg product or material for final deposition)	

L) Preparation of information on potential benefits and loads beyond the discard products end-of-life (D)

Module D which is voluntary additional information includes information that describe potential environmental benefits and loads if the analysed product is reused, material recycled or energy recovered. As mentioned earlier, the result from D shall not be added nor compared to the result from stage A to C and shall therefore be reported separately. The environmental performance reported in D may be used to give information on different handling options of the recovered material. The environmental performance reported here goes beyond the initial discard products lifecycle (reported in stage A to C). The purpose of addressing this module is to support an efficient use of natural resources and reduced environmental impact when handling the scraped product.

The information in D is highly dependent on the inventory flows reported in module C3. Thus, C3 constitutes the source information used as input for the calculations in D. Required information to specify these scenarios are presented in **TABLE 10.**

TABLE 10 | TYPICAL INFORMATION REQUIREMENTS FOR THE DEVELOPMENT OF REUSE, RECYCLING AND ENERGY RECOVERY RELATED SCENARIOS

MODULES	INFORMATION REQUIRED FOR THE DEVELOPMENT OF SCENARIOS
Reuse	» Information on the upgrade treatment/ processing performed before the product is put on the market again
	» All the necessary information for the development of scenarios identified for modules A4-C4 for the (upgraded) product
Recycling	» Description of the best case current practice
	» Description of the current practice
	» Description of the worst case
	» kg of secondary material delivered to the market in case the best practice is followed
	» kg of secondary material delivered to the market in case the current practice is followed
	» kg of secondary material delivered to the market in the worst case scenario
Recovery	» Description of the best case current practice
	» Description of the current practice
	» Description of the worst case
	» MJ of secondary fuel delivered to the market in case the best practice is followed
	» MJ of secondary fuel delivered to the market in case the current practice is followed
	» MJ of secondary fuel delivered to the market in the worst case scenario

4. COMPILATION AND ANALYSIS - REPORTING AND COMMUNICATION

It is important to consider an effective communication of the product's embodied impact, as communicating on progress will drive deeper engagement with stakeholders. This can help an enterprise to meet its goals, enhance profits and reputation, and therefore ensure a good return on investment on the assessment itself. Promoting high levels of transparency in communication and interpretation can inspire confidence in results, enables the proper use of embodied impacts figures both for B2B and B2C marketing and mitigates against potential criticism SMEs may face on the dissemination of their results.

Public communication means that the results are not only communicatedto the consumer market (B2C), but also to other interested parties. This can be used to distinguish your company from any other company operating in the same market (producing products of the same product type) and can be done through the point of sale, reporting, advertising and labelling. Public communication of results requires a high level of accuracy, so to enable product to product comparisons - but only for comparability purposees. Manufacturers are recommended to inform themselves on the PEF (product environmental footprint) discussion status.

For B2C communication, it is recommended to use recognized, credible and third party certified labels, such as the Type I labels defined in the ISO 14024 Standard – please check **TABLE 11**.

Another form of communication is the passing of information down the supply chain when this data is requested by a customer of your product (in a B2B situation). In these situations, the accuracy level required can vary. Engaging and communicating backwards in the supply chain also means that information gathered during the process can help suppliers reduce their embodied impacts and thus the impacts of your product.

External reporting can include a summary of the assessment results on a website or in a CSR (corporate social responsibility) report, where the audience will include both consumers but more likely investors in your company and other interested stakeholders. Detailed results and evidence may not be required in these cases.

For increasing credibility, a manufacturer may choose to comply with certain standards (e.g. EPD standards) and thus include set 'reporting' requirements, and complete set communication templates. EPD's are one possibility (Type III declarations), however, they require the comprehensive results of an LCA including a variety of impact categories. The types of EPD with respect to life cycle stages covered are presented in **FIGURE 14** section 05.

Here, it is recommended for each module to indicate individual data/information about embodied impacts for different scenarios – e.g. individual data for different possibilities/options of transport (A4) or installation (A5). Thus, several case specific modules (information packages) can be included in the same module based on the number of typical scenarios that can be identified by the manufacturer - e.g. structured as proposed in **FIGURE 15**.

TABLE 11 | INFORMATION ON THE DIFFERENT TYPES OF ENVIRONMENTAL LABELS AND DECLARATIONS

ENVIRONMENTAL LABELS AND DECLARATIONS
TYPE I ENVIRONMENTAL LABELS AS DEFINED IN ISO 14024:
» Are aimed at both private and business consumers, » Declare that a product has a particular environmental attribute, » Are relevant to public procurement, » Have a high level of credibility and are usually very well known, » Require third-party certification, » Involve all interested parties.
TYPE II ENVIRONMENTAL LABELS AND DECLARATIONS THAT MEET ISO 14021:
» Are primarily aimed at consumers, » Often focus on one specific environmental aspect, » Can also in principle be used to convey complex information, » Are based on voluntary self-declarations for which the manufacturer has sole responsibility
TYPE III DECLARATIONS AS DEFINED IN ISO 14025:
» Are aimed at manufacturers in the supply chain, commerce and trade, rather than consumers, » Are based on a life cycle assessment, » Provide comprehensive quantitative and verified information, » Provide data on environmental performance without any evaluation, » Are suitable for all products and services, » Make it possible to aggregate data across the entire value chain, » Require independent verification by a third party.

The manufacturers' intention should be to provide as much information as possible to support the development of the scenarios at the building level. Within the EPD context, the manufacturer is not only requested to describe one or two typical scenarios for each downstream information module, but also to respond to a possible future development of EPDs, and to support designers and other stakeholders in a better way. To do this, different "case-based information packages" for each information module will need to be provided.

An important issue for the further development of EPD's is the development of severall case specific information packages for each module describing downstream processes (A4-C4 & D) to allow the users of the information (e.g. designers) to select which information package is more relevant to their building case - see **FIGURE 15**.

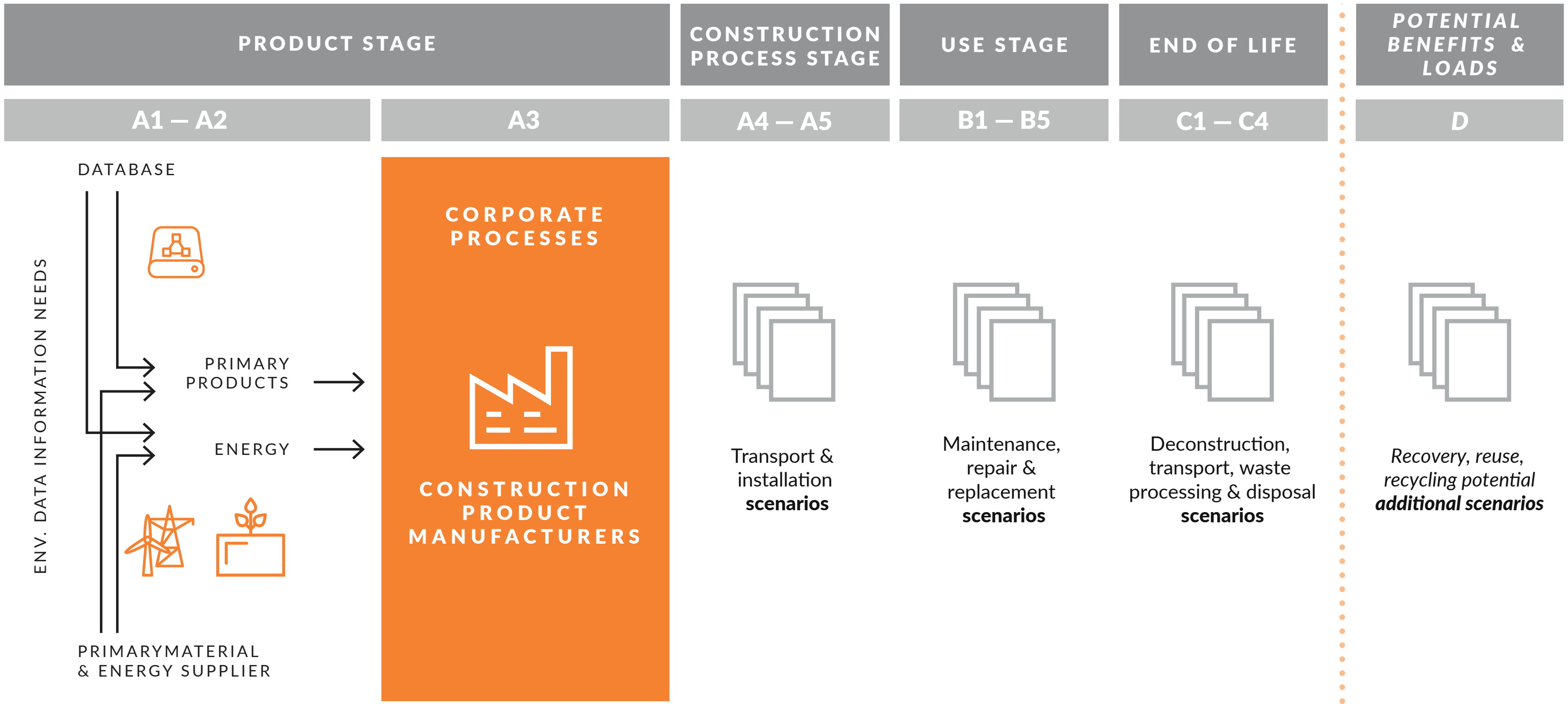


FIGURE 15 | MODULAR SCENARIO DEVELOPEMENT (BASED ON LÜTZKENDORF & BALOUKTSI, KIT, 2016)

DECIDING WHICH DATASET TO USE

Data collection is one of the key challenges (and sometimes a barrier) to completing an assessment of embodied impacts, especially when data is needed down the supply chain and not just for company activities. Data used for product assessments can be divided into two main categories:

- Internally collected data (own company, generated by the manufacturer), and
- Externally collected (outside company from the supply chain)

Internally collected data are physical data directly attributable to the specific product being investigated. Externally collected data includes energy and emission factors which can be used in calculations to determine embodied energy or GHG emissions per functional unit.

A. INTERNALLY COLLECTED DATA

The physical data required for an embodied impacts analysis involves units such as weight, distances and energy consumption. Successful data gathering requires an organization to assign time and human resources to the data gathering process. It is common for this type of data to be gathered from different departments within the organization, so it is a good practice to assign a coordinator to the process. Specific data required for the quantification and assessment may be retrieved using the following sources:

a. Utilities

Data on utility media such as water, electricity (e.g. kWh) or natural gas (kWh or m^3) use, can be obtained from utility bills or meter records. In cases, sub-metering of product specific processes is available, consumption quantities can be obtained from there.

b. Materials

Materials used during the manufacturing process include not only raw materials and pre-products used to make the product, but also auxiliary materials that are attributable to the production process. These can include cleaning chemicals, product packaging, or energy sources. for in utilities among others. Product specification, bill of materials or invoices can be used as sources for the composition and weight of these materials.

c. Transport

Data on incoming and outgoing freight transport can be obtained from expenses claims, vehicle records, fuel cards, or surveys. Expenses claims can be directly associated with fuel costs and hence with fuel consumed. If vehicle types are known, average fuel use rates could be multiplied by known distances to obtain total fuel consumption. Although fuel consumption data is more accurate, in some cases, there are publicly available data from specialist organizations (externally collected data). These data can be used to calculate the impacts of transport knowing the distance covered.

d. Waste

Waste data required includes the material type, weight of waste, and the waste management option used (e.g. landfill, recycled). Data can typically be obtained from waste contractor records. When these are not available a waste survey can be undertaken over a representative period of time to determine the type, weight and management of waste.

B. EXTERNALLY COLLECTED DATA

Small and medium-sized enterprises are in a position to determine the amount of energy as well as the type and quantity of primary and auxiliary products that go into their own processes. They are also in a position to estimate the cost of internal transport as well as the transport modes and distances for the delivery of primary and auxiliary products. This information must be combined with primary energy and emission coefficients. The manufacturer – or the service providers/ consultants acting on their behalf – in order to determine the product-related information on the primary energy consumption and the resulting emissions of greenhouse gases – need to acquire data from external sources. This includes information about processes, over which the manufacturers have no direct influence. The direct influence focuses on the design of their own processes (choice of technology), the management of the delivery processes and the selection of primary and auxiliary products. Different types of data sources, from where the embodied energy and emissions coefficients for primary products, auxiliary products and energy and transport services can be sourced, are:

a. Information from suppliers and service providers

Information on the primary energy consumption and the resulting GHG emissions for primary products, auxiliary products, and energy and transportation services can be directly obtained from the material/ product suppliers and service providers. What they usually offer is either the results of specific LCAs or product/ process-specific environmental product declarations (EPD's). Care must be taken to ensure that this information includes all the related upstream processes and are based on a uniform system. It is recommended to regulate the supply of appropriate information with the suppliers/service providers in a contractually binding way.

It is possible that certain suppliers/service providers do not have specific LCAs/EPD's for their products/services but instead they offer as an alternative the association/industry average data (Sector or generic EPD). Their use is permitted, but must be listed separately.

b. Databases

Various databases are available for primary energy and emission factors. These can be based on data that emerged as a result of process chain analysis, I-O tables or hybrid approaches or any combination of these approaches. The data incorporated into these databases are usually obtained either from an LCA or the evaluation of published EPD's. A quality control should be ensured. There are the following types of databases among others:

» National LCA databases

These are freely accessible databases, adapted to national context, such as published or unpublished literature sources, that were created and are being maintained with public funds, and therefore they are subject to a quality control. If existent, these should be preferred.

» Commercial LCA databases

There are commercial database providers, who can provide their services. The access to such databases is usually chargeable. The data derived from these databases may be average (combined from different suppliers for the same material), product collective (e.g. LCA at the association level established for a type or a category of similar materials), or product specific (LCA at the supplier level). However, the quality of the available databases in each country varies (with/without (external) quality control). Thus, the quality assessment of the used data set is very important.

» Databases with LCA data from trade associations

Many trade associations or bodies have already created and published LCAs for the type of construction products they represent. These can be with or without (external) quality control.

» Databases with transport distances

A special case is the databases with average distances for the transport. They can be used in case no concrete information on transport distances can be determined.

c. Published or unpublished literature sources

This type of data is usually of unclear origin and therefore may be used only when all the others types of data are not available.

C. DATA QUALITY CHALLENGES

The quality assessment of the used data set is very important. A few questions to use in the database selection are listed in the report of GHG Protocol "Product Life Cycle and Accounting and Reporting Standard":

1. Are the process data from a collection of actual processes or estimated/calculated from other data sources?
2. Were the data developed using a consistent methodology?
3. For agricultural and forest products, are land-use impacts included in the LCA emissions data? If yes, which impacts are included?
4. How long has the database existed, and how extensively has the database been used?
5. How frequently is the database updated?
6. How current are the data sources used for developing the LCA emissions data?
7. Can uncertainties be estimated for the data?
8. Is there any risk that the data will be perceived as biased and, if so, have the data and methodologies been independently reviewed?

Once an appropriate database(s) is selected, manufacturers are required to perform a data quality and "fit-for purpose" assessment also of the individual data chosen from the selected databases. The same report of GHG Protocol identifies 5 important data quality indicators (**TABLE 12**). The outcome of any data quality assessment performed should be documented to assist results interpretation and highlight areas for future improvement.

TABLE 12 | DATA QUALITY INDICATORS – ADAPTED FROM GHG PROTOCOL REPORT "PRODUCT LIFE CYCLE AND ACCOUNTING AND REPORTING STANDARD" (2011)

INDICATOR	DESCRIPTION
Technological representativeness	The degree to which the data set reflects the actual technology(ies) used
Temporal representativeness	The degree to which the data set reflects the actual time (e.g., year) or age of the activity
Geographical representativeness	The degree to which the data set reflects the actual geographic location of the activity (e.g., country or site)
Completeness	The degree to which the data is statistically representative of the relevant activity. Completeness includes the percentage of locations for which data is available and used out of the total number that relate to a specific activity. Completeness also addresses seasonal and other normal fluctuations in data.
Reliability	The degree to which the sources, data collection methods and verification procedures used to obtain the the data are dependable.

CONCLUSION

Nowadays, clients, procurers and designers, seek to select construction products to fulfill not only the requirements on the functional and technical quality and economic aspects, but also to contribute to the conservation of resources and the reduction of adverse effects on the environment as part of an overall strategy for sustainable design and construction. It is no surprise that currently construction product manufacturers are being asked to step up to this challenge and reduce the embodied impacts of their products. At the same time, they are being increasingly asked to report their impacts in a transparent and accountable way in order to enable the consumers to make informed decisions about the products they purchase.

Considering also that within the framework of sustainability assessment labels (e.g. LEED, BREEAM or DGNB) it is increasingly required to perform a full Life Cycle Assessment (LCA) for buildings, and that LCA data on construction products provide the basis for this, a need for such information is evident.

Small and medium enterprises, seeking to improve their market competitiveness, to show good ethics and to take responsibility for environment and society, are usually hindered by lack of resources and limited access to information. This guideline offers a way to complete a simple calculation and assessment of embodied impacts of a construction product throughout its life cycle. Such an assessment may be used both for identifying potentials for internal improvement (e.g. of production or procurement processes) or external communication to other stakeholders (e.g. B2B or B2C communication).

Construction product manufacturers, can unlock their potential of influencing their products' embodied energy and global warming potential through, for example:

- choosing specific primary raw materials, energy sources and technologies for the manufacturing process.

- advancing the technical characteristics of their products in terms of durability, maintainability and serviceability, as well as ease of dismantling, reuse and recyclability.

- expanding their scope on the product lifecycle through the provision of life cycle support services (e.g. maintenance contracts) and take back programs at the end of the product's service/useful life.

- technically advising and supporting clients and architects on how to better install and use their products(maintenance instructions)

The recommendations provided within this guideline are intended for the collection of data (internally and third party) as well as recommendations for the communication of information (e.g. by the use of environmental informations or environmental product declarations - EPDs). The provision of "better" products in combination with the publication and active handover of credible environmental product information supplementing the information on the technical and functional characteristics of the product, as well as the transition to life cycle support services, can significantly improve the competitive position of SMEs.

ABBREVIATIONS AND GLOSSARY

ABBREVIATIONS

AEC	Architecture, Engineering and Construction Professionals
B2B	Business-to-Business
B2C	Business-to-Consumer
BIM	Building Information Modelling
BNB	German rating system for sustainable building, www.bnb-nachhaltigesbauen.de
BREEAM	Building Research Establishment Environmental Assessment Methodology — sustainability assessment and certification system for buildings (UK) www.breeam.com/
BSI	British Standards Institution
BWR	Basic requirement for construction works; referred to as basic works requirement
CE-marking	The CE marking indicates a product's compliance with EU legislation (CPR)
CEN	European Committee for Standardization
CO_2eq.	CO_2 equivalent — a unit of measurement that is based on the relative impact of a given gas on global warming (the so called global warming potential).
CPR	Construction Products Regulation (EU) No 305/2011
DGNB	German rating system for sustainable building, www.dgnb.de/en
EBC	Energy in Buildings and Communities Programme
EE	Embodied Energy
EEG	Embodied Energy and GHG Emissions
EG	Embodied GHG Emissions
EI	Embodied Impacts
EN	European Standard
EoL	End of Life
EPD	Environmental Product Declaration
GCPM	Guideline for construction product manufacturers
GHG	Greenhouse gases – they are identified in different IPCC reports

GWP	Global Warming Potential – A relative measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is measured against CO_2e which has a GWP of 1
HFC	Hydrofluorocarbon – An HFC gas is a gas which can be used in a number of different applications. HFCs are commonly seen in use in construction products, for example, as refrigerants in cooling systems such as refrigerators or as blowing agents in insulation materials.
HQE	High Quality Environmental standard – a standard fort green building in France
HVAC	heating, ventilating, and air conditioning
IEA	International Energy Agency
IOTs	Input-Output Tables
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LEED	Leadership in Energy and Environmental Design – sustainability assessment and certification system for buildings (US)
PAS	Publicly Available Specification
PE_t	Primary Energy total
RSL	Reference Service Life
REACH	European Community Regulation on chemicals and their safe use (EC 1907/2006). It deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances
SCP	Sustainable Consumption and Production
SIA	The Swiss Society of Engineers and Architects, http://www.sia.ch/en/the-sia/
SME	Small and medium-sized enterprises
SPF	Spray Polyurethane Foam
ST1	Subtask 1 is one of the five subtasks of Annex 57 project. It deals with the basics, actors and concepts related to EE and EG
ST3	Subtask 3 is one of the five subtasks of Annex 57 project. It deals with the creation of EE and EG data
TQB	Total Quality Building Assessment – building assessment scheme in Austria, https://www.oegnb.net/en/tqb.htm
UNEP-SBCI	United Nations Environment Programme – Sustainable Buildings & Climate Initiative, http://www.unep.org/sbci/
VDI	The Association of German Engineers, http://www.vdi.eu/
XPS	Extruded Polystyrene

GLOSSARY

Allocation The sub-division of input and output flows between one or more product systems

Cradle to Gate This boundary includes only the production stage of the construction products integrated into the building. Processes taken into account are: the extraction of raw materials, transport of these materials to the manufacturing site and the manufacturing process of the construction products itself. Thus, in the case of a building the impacts of this stage are accounted for as the sum total of the "cradle to gate" impacts of its individual components.

Cradle to Site Cradle to gate boundary plus delivery to the site of use.

Cradle to Handover Cradle to site boundary plus the processes of construction and assembly on site.

Cradle to End of Use Cradle to handover boundary plus the processes of maintenance, repair, replacement and refurbishment, which constitute the recurrent energy. This boundary marks the end of first use of the building.

Cradle to Grave Cradle to handover plus the use stage, which includes the processes of maintenance, repair, replacements and refurbishments (production and installation of replacement products, disposal of replaced products) and the end of life stage, which includes the processes of demolition, transport, waste processing and disposal (grave).

Embodied Energy Embodied Energy (sometimes also called cumulative energy demand) is a method of accounting for the primary energy resources (regardless of their type) consumed/used in one or more life cycle stages of a given product (of a given functional equivalent), other than the ones related to the direct use of the product or to the operation of the construction work (this applies only to buildings and products relevant for the energy supply of a building).

Embodied GHG Emissions Embodied GHG Emissions (sometimes also called embodied carbon, carbon footprint or embodied global warming potential) is a method of accounting for the amount of greenhouse gases (regardless of their type and source) emitted during one or more life cycle stages of a given product (of a given functional unit), other than the ones related to the direct use of the product or to the operation of the construction work (this applies only to buildings and products relevant for the energy supply of a building).

Embodied Impacts Embodied impacts refer in this document only to the primary energy consumption and the adverse effects on the climate resulting from GHG emissions that arise in the life cycle of construction products due to their production, installation into the building or construction works, maintenance and end of life; the so-called embodied energy and embodied GHG emissions.

Feedstock (Energy) Heat of combustion of a raw material input that is not used as an energy source to a product system, expressed in terms of higher heating value or lower heating value. Thus, this represents the non-energy-related use of energy resources. This could be non-renewable (fossil) or renewable (biomass).

Gate to Gate This boundary looks only at the corporate processes (processes within the enterprise's boundary) in the entire production chain.

Process related Emissions Non-fuel related CO_2 emissions emitted during the manufacturing processes of some construction products as a result of specific chemical effects (e.g. CO_2 is emitted as a chemical reaction in cement manufacture).

Stored Carbon Biogenic carbon stored over a specific period of time

Upstream process Process that is carried out before the designated process (here the manufacturing process) in the stream of relevant processes

Downstream process Process that is carried out after the designated process (here the manufacturing process) in the stream of relevant processes

REFERENCES & SOURCES OF FURTHER INFORMATION

Guidelines and Initiatives from various organisations

ST1
Lützkendorf, T., Balouktsi, M., Frischknecht, R. (2016). Evaluation of Embodied Energy and CO2eq. in Building Construction (Annex 57) - Subtask 1: Basics, Actors and Concepts, IEA EBC Annex 57, www.annex57.org

ST3
Seo, S., Foliente, G. Yokoyama, K., Frischknecht, R., Dixit, M. (2016). Evaluation of Embodied Energy and Co2eq. in Building Construction (Annex 57) - Subtask 3: Evaluating the Embodied Energy and the Embodied GHG in Building and Construction: Review of Methods, Emerging Research and Practical Guidelines, IEA EBC Annex 57, www.annex57.org

Construction Products Association A guide to understanding the embodied impacts of construction products,
www.constructionproducts.org.uk/?eID=dam_frontend_push&docID=531&filename=Embodied_Impacts_brochure_small_V9.pdf

European Network of Construction Companies for Research and Development (ENCORD) Construction CO_2e Measurement Protocol - A Guide to reporting against the Green House Gas Protocol for construction companies,
www.encord.org/wp-content/uploads/2012/06/ENCORD_CO2e_Protocol.pdf

Royal Institute of Chartered Surveyors (RICS) information paper Methodology to calculate embodied carbon of materials,
www.ice.org.uk/ICE_Web_Portal/media/northeast/Methodology_embodied_carbon_materials_final---1st-edition.pdf

Waste and Resource Action Programme (WRAP) Procurement requirements for carbon efficiency Guidance for low-carbon building projects and estates management,
www.wrapni.org.uk/sites/files/wrap/Procurement%20Requirements%20for%20carbon%20efficiency%20FINAL.pdf

STANDARDS

CEN TC350 is series of voluntary standards for assessing the sustainability of construction products at building level which are currently being developed by the European Commission, www.cen.eu/cen/Sectors/Sectors/Construction/SustainableConstruction/Pages/CEN_TC350.aspx

Construction Products Association A guide to understand embodied impacts. The purpose of this guide is to improve understanding across the construction industry. http://www.constructionproducts.org.uk/publications/sustainability/a-guide-to-understanding-the-embodied-impacts-of-construction-products/

Greenhouse Gas Protocol - Product Life Cycle Accounting and Reporting Standard. World Resources Institute – WBCSD. www.ghgprotocol.org/files/ghgp/Product%20Life%20Cycle%20Accounting%20and%20Reporting%20Standard.pdf

SIA 2040 The objective of the SIA's Energy Guidelines for Buildings is to establish a consistent and sustainable basis for Switzerland's building stock and encourage intelligent use of the resource energy. http://www.sia.ch/de/themen/energie/effizienzpfad-energie/

ISO 15392 is the framework for the development of indicators and a core set of indicators for buildings. Its focus is ther sustainability in building construction. http://www.iso.org/iso/iso_technical_committee?commid=322621

PAS 2050 is a Publicly Available Specification (PAS) for a method for measuring the embodied greenhouse gas emissions from goods and services. http://www.stop-climate-change.de/unsere-standards/pas-2050/

VDI 4600 is a guideline for the culminated energy input that is needed for production, usage and disposal of economic goods (products or service) https://www.vdi.de/technik/fachthemen/energie-und-umwelt/fachbereiche/ressourcenmanagement/liste-aller-richtlinien/vdi-4600/

ISO TC59 / SC17 is the technical committee which is responsible for a suite of standards related to sustainability in buildings and civil engineering works. http://www.iso.org/iso/iso_technical_committee?commid=322621

ISO/TS 14067 Greenhouse gases, Carbon footprint of products, Requirements and guidelines for quantification and communication, specifies principles, requirements and guidelines for the quantification and communication of the CFP, based on International Standards on life cycle assessment (ISO 14040 and ISO 14044) for quantification and on environmental labels and declarations (ISO 14020, ISO 14024 and ISO 14025) http://www.iso.org/iso/catalogue_detail?csnumber=59521

TOOLS AND DATA SOURCES | PUBLICLY AVAILABLE

Environmental Profiles are available at www.greenbooklive.com where their LCIA and Green Guide ratings can also be viewed.

» Environment Agency Carbon Calculator for Construction Envest2 (UK) | envest2.bre.co.uk
» Elodie (French) | www.elodie-cstb.fr
» LISA (Australian) | www.lisa.au.com
» GaBi Build-IT (German)
» LCADesign (Australian) | www.ecquate.com
» The Technology Strategy Board Low Impact Buildings "Design and Decision Tools" call is funding 12 projects, many of which will calculate embodied CO2
» EU funding CILECCTA project linking LCA, LCC and BIM

ACLCA The American Center for Life Cycle Assessment (ACLCA) is a nonprofit membership organization advancing the science and application of life cycle assessment (LCA) to build capacity, drive development and connect the LCA community to achieve environmental sustainability
www.lcacenter.org

BRE"s Green Guide to Specification. The UK construction products sector has worked with BRE over the past 15 years to develop a LCA database for nearly 2,000 of the most significant and common products used in constructing buildings. This database includes information on all stages of the life cycle, including disposal, and has been developed to a consistent methodology (BRE Environmental Profiles Methodology) based on data provided by the industry. The data are being made available at
www.bre.co.uk/greenguide

Bau EPD GmbH is running the Austrian programme for the issue of Environmental Product Declarations (short: EPD) for construction-related products.
www.bau-epd.at/en

BuildCarbonNeutral is a Construction Carbon Calculator that helps developers, builders, architects and land planners approximate the net embodied carbon of a project's structures and site.
www.buildcarbonneutral.org

CapIT Carbon and Cost Estimator is an online system allowing users to estimate cost and embodied carbon values for construction activities.
www.franklinandrews.com/publications/capittool/

CEC The China Environmental United Certification Center is enforcing the requirement concerning improving the technique and quality of certification which is issued by SEPA
www.sepacec.com/cece

CENDEC The Centre for Environmental Product Declarations is an association consisting of experts for LCA and EPD in the Czech Republic focusing on eco-labeling
cendec.cz

EcoLeaf EcoLeaf environmental label uses the LCA method to quantitatively show the environmental information of products through life cycle stages from the extraction of resources to manufacturing, assembly, distribution, use, discarding and recycling.
www.ecoleaf-jemai.jp/eng/

ECOproduct is a method and database assisting in environmental selections of materials and products within a project. ECOproduct was developed by a co-operation between SINTEF Building and Infrastructure, Norsk Byggetjeneste and NAL-Exobox.
www.sintef.no/home/Building-and-Infrastructure/Buildings/Climate-and-Environment/ECOproduct---Environmental-selection-of-building-materials-and-products/

EDF The Environment and Development Foundation is a Taiwanese Provider of green product certification services, as well as a promoter of green consumption
www.edf.org.tw/english

The international EPD system The International EPD System is a programme for voluntary and transparent communication of the life cycle environmental impact of goods and services.
www.environdec.com

The Environment Agency has developed a free calculator for estimating the carbon footprint from construction materials and activities on site.
www.environment-agency.gov.uk/business/sectors/37543.aspx

EPD-Norway With EPD Norway you get verified, approved and registered EPDs as well as help to find experts for the preparation of EPDs
www.epd-norge.no

The European Life Cycle Database (EU Joint Research Centre). The ELCD comprises Life Cycle Inventory (LCI) data from front-running EU-level business associations and other sources for key materials, energy carriers, transport, and waste management.
eplca.jrc.ec.europa.eu/ELCD3/

IBO Baustoffdatenbank The platform is a info-communication hub for energy-efficient and ecological construction. It supports sustainable construction projects and healthy living, reflected in the information it offers.
www.baubook.at

INIES. Consulter les Fiches de Déclaration Environnementaleet Sanitaire (FDES) des Produits de construction.
www.inies.fr/IniesConsultation.aspx

Institut Bauen und Umwelt e.V.(IBU) Environmental product declarations (EPD).
www.bau-umwelt.de/hp481/Environmental-Product-Declarations-EPD.htm

KBOB recommendations 1/2009 LCA data for building construction. This database contains free LCI data for construction materials, building installations, transportation and energy processes, based on Ecoinvent data.

KEITI Mission of the Korea Environmental Industry & Technology Institute is to contribute to sustainable development through technology development, industry murtutring and eco-friendly lifestyle promotion
eng.keiti.re.kr

Ökobau.dat database in Germany – only available in German
www.nachhaltigesbauen.de/baustoff-und-gebaeudedaten/oekobaudat.html

openLCA a free, professional Life Cycle Assessment (LCA) and footprint software with a broad range of features and many available databases, created by GreenDelta
www.openlca.org

U.S. LCI Database (National Renewable Energy Laboratory NREL). This database contains processes of gate-to-gate, cradle-to-gate and cradle-to-grave data sets, covering the energy and material flows that are associated with producing a material, component, or assembly in the U.S.
www.nrel.gov/lci

EBC

Energy in Buildings and Communities Programme

IEA EBC ANNEX 57 | GUIDELINES FOR CONSTRUCTION PRODUCT MANUFACTURERS

The preparation of this guideline was part of the Austrian contribution to the IEA EBC Annex 57, which is financially supported by the Austrian Research Promotion Agency (FFG) and the Austrian Ministry for Transport, Innovation and Technology (BMVIT), Grant #6069077 IEA RSEARCH ERATION

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iea Energy Technology Network